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Kajita et al.

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(54) **CONTROL DEVICE AND WORKING MACHINE**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

7,234,298 B2 * 6/2007 Brinkman E02F 9/2217
60/414
8,209,975 B2 * 7/2012 Persson F15B 21/14
60/413

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2008-185099 A 8/2008
JP 2008-196165 A 8/2008

(Continued)

OTHER PUBLICATIONS

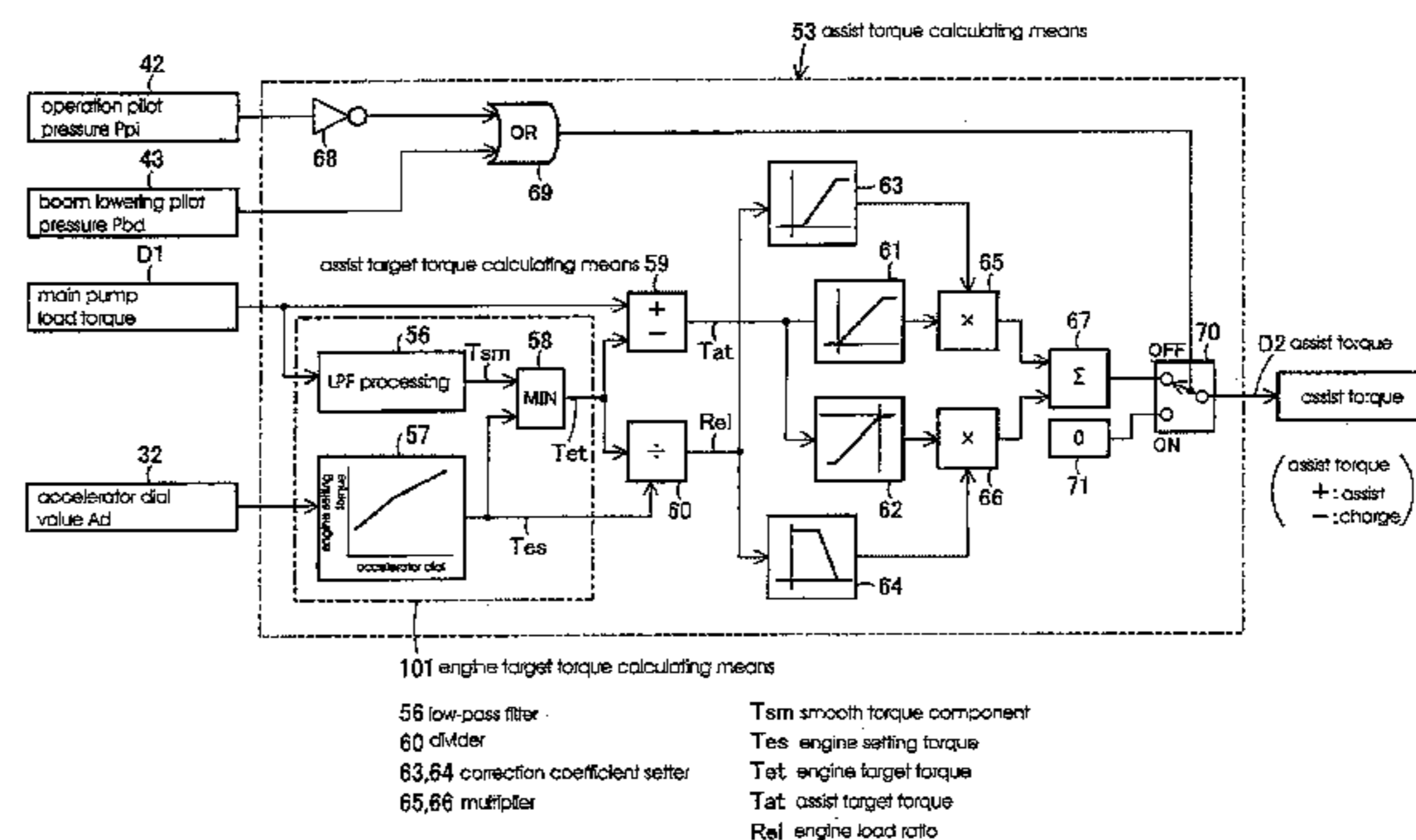
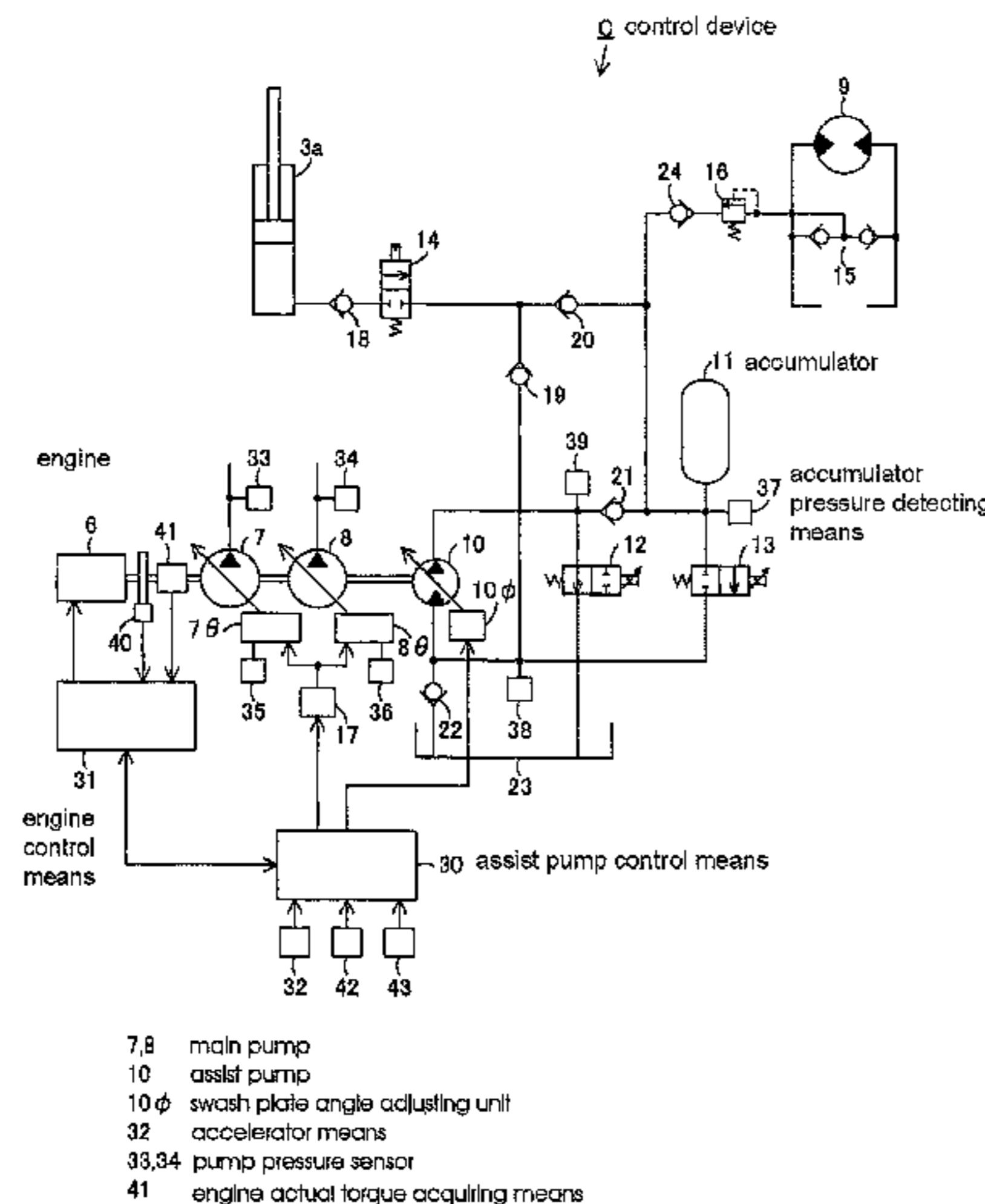
European Patent Office, International Search Report in International Patent Application No. PCT/EP2015/058433, dated Jul. 17, 2015, 2 pp.

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(57) **ABSTRACT**

A control device for suppressing engine load fluctuation according to main pump circuit conditions, wherein an assist torque calculation task includes a target engine torque calculation task separating smooth torque components from main pump load torque and setting a minimum value of either smooth torque component or engine setting torque as target engine torque, and a subtractor calculating target assist torque based on a difference between the main pump load torque and the target engine torque, the assist torque calculation task controlling a capacity of an assist pump based on the target assist torque and controlling switching between an assist mode and a charge mode.

6 Claims, 11 Drawing Sheets



7,8 main pump
10 assist pump
10φ swash plate angle adjusting unit
32 accelerator means
33,34 pump pressure sensor
41 engine actual torque acquiring means

58 low-pass filter
60 divider
63,64 correction coefficient setter
65,66 multiplier
Tsm smooth torque component
Tes engine setting torque
Tet engine target torque
Tat assist target torque
Rel engine load ratio

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E02F 9/22 (2006.01)
E02F 3/96 (2006.01)
F15B 11/10 (2006.01)
F15B 13/04 (2006.01)

USPC 60/428, 429, 430, 445
 See application file for complete search history.

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F15B 11/10 (2013.01); *F15B 13/0416*
 (2013.01); *E02F 9/2285* (2013.01); *F15B*
2201/51 (2013.01); *F15B 2211/605* (2013.01);
F15B 2211/633 (2013.01); *F15B 2211/6306*
 (2013.01); *F15B 2211/6333* (2013.01); *F15B*
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 (2013.01); *F15B 2211/6656* (2013.01); *F15B*
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 (2013.01); *F15B 2211/763* (2013.01); *F15B*
2211/765 (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,874,327	B2 *	10/2014	Ishihara	.....	E02F 9/2246
					701/50
9,126,587	B2 *	9/2015	Yamazaki	.....	B60W 20/19
9,279,236	B2 *	3/2016	Zhang	.....	E02F 9/2217
9,399,856	B2 *	7/2016	Fujishima	.....	B60W 20/00
9,593,467	B2 *	3/2017	Kajita	.....	F15B 21/14
2010/0218493	A1 *	9/2010	Nakamura	.....	E02F 9/2235
					60/426
2013/0006457	A1	1/2013	Anders et al.		
2015/0192149	A1 *	7/2015	Ma	.....	F15B 1/0275
					60/327

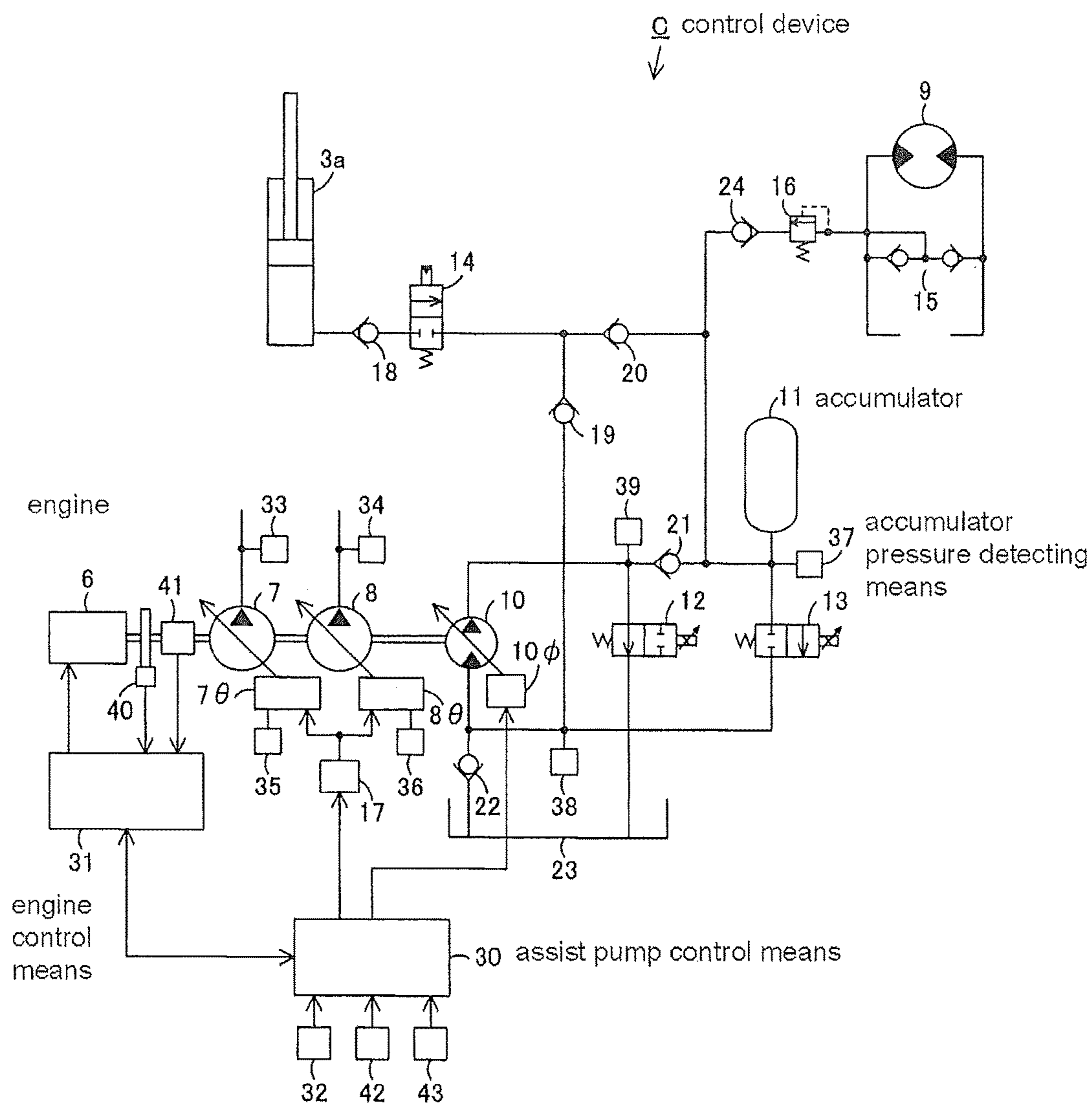
FOREIGN PATENT DOCUMENTS

JP	2009-275773	A	11/2009
JP	2010-084888	A	4/2010
JP	2006-322578	A	11/2016
WO	WO 2014/115645	A1	7/2014

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2211/633; *F15B 2211/6346*; *F15B*
2211/6333; *F15B 2211/6656*; *F15B*
2211/6658; *F15B 2211/6651*

* cited by examiner

Fig. 1



- 7,8 main pump
- 10 assist pump
- 10φ swash plate angle adjusting unit
- 32 accelerator means
- 33,34 pump pressure sensor
- 41 engine actual torque acquiring means

Fig. 2

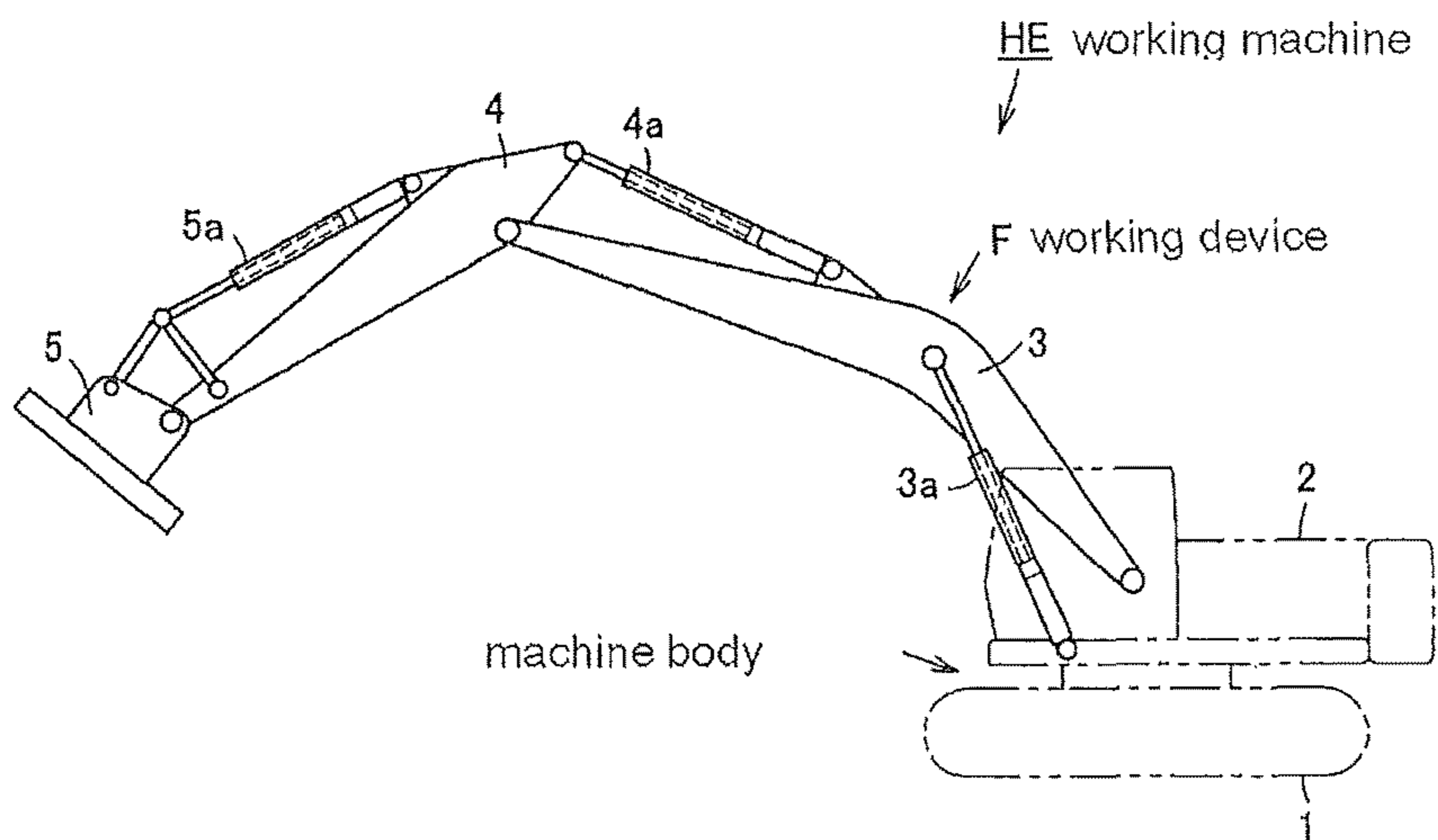


Fig. 3

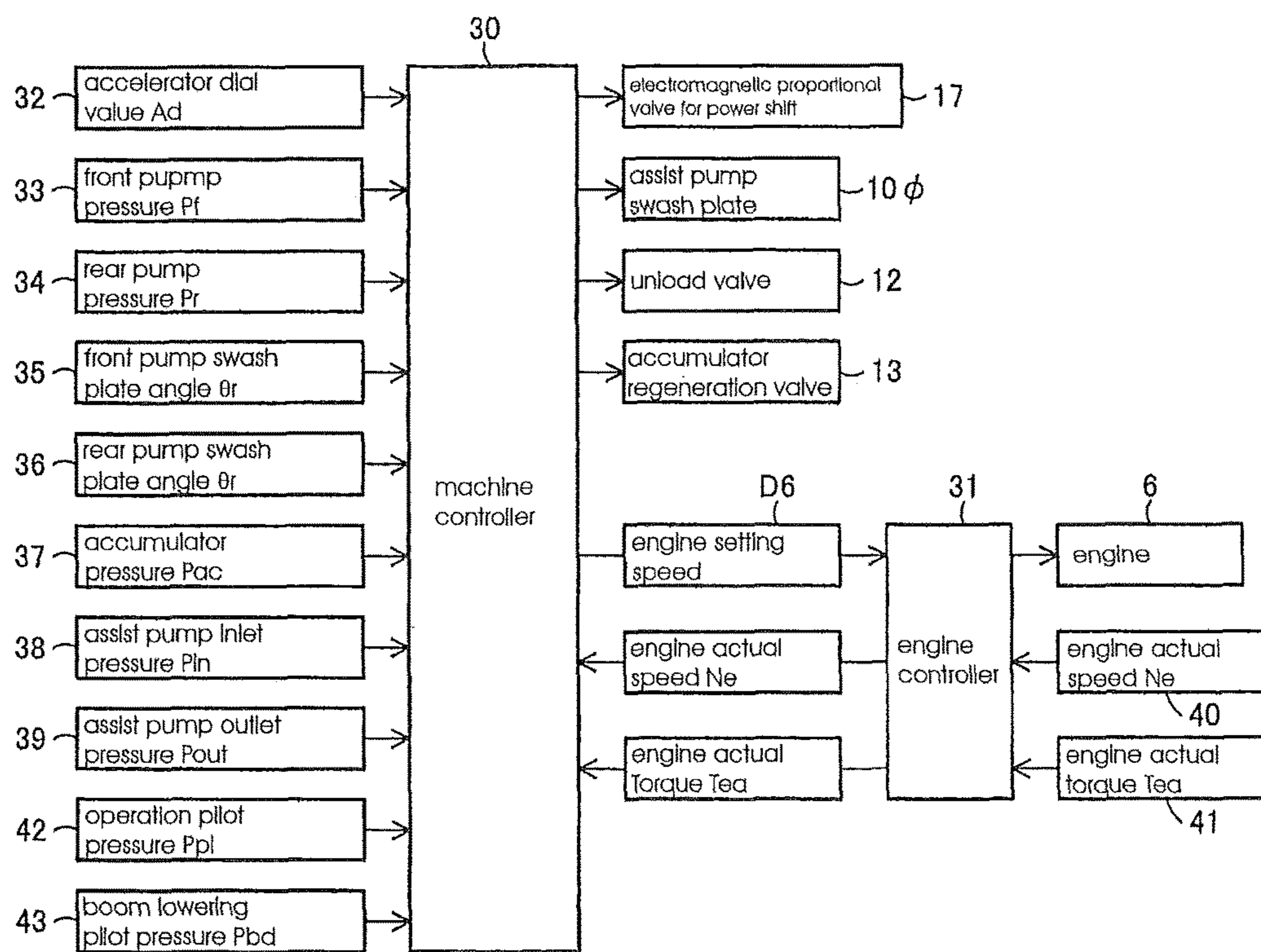
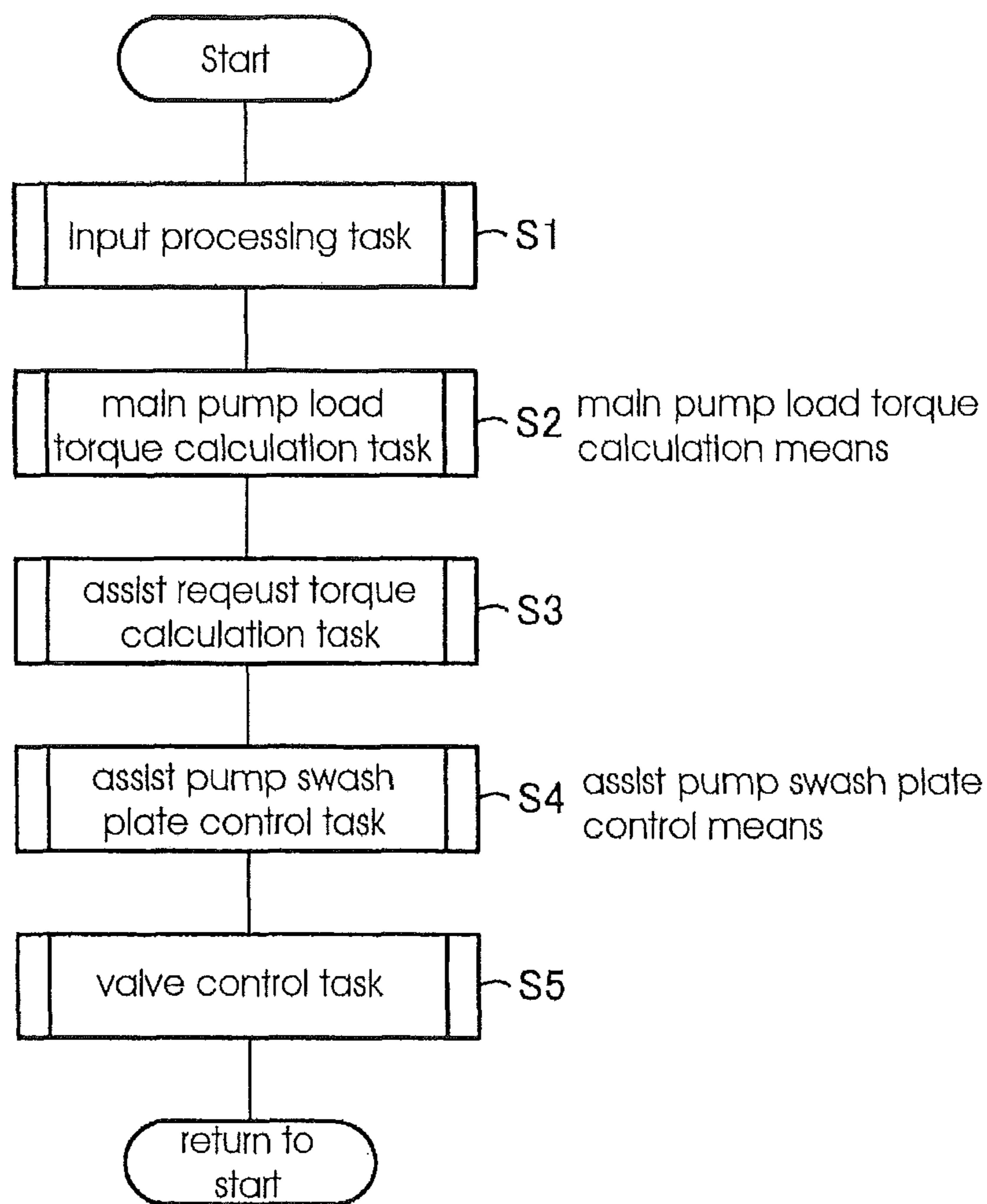
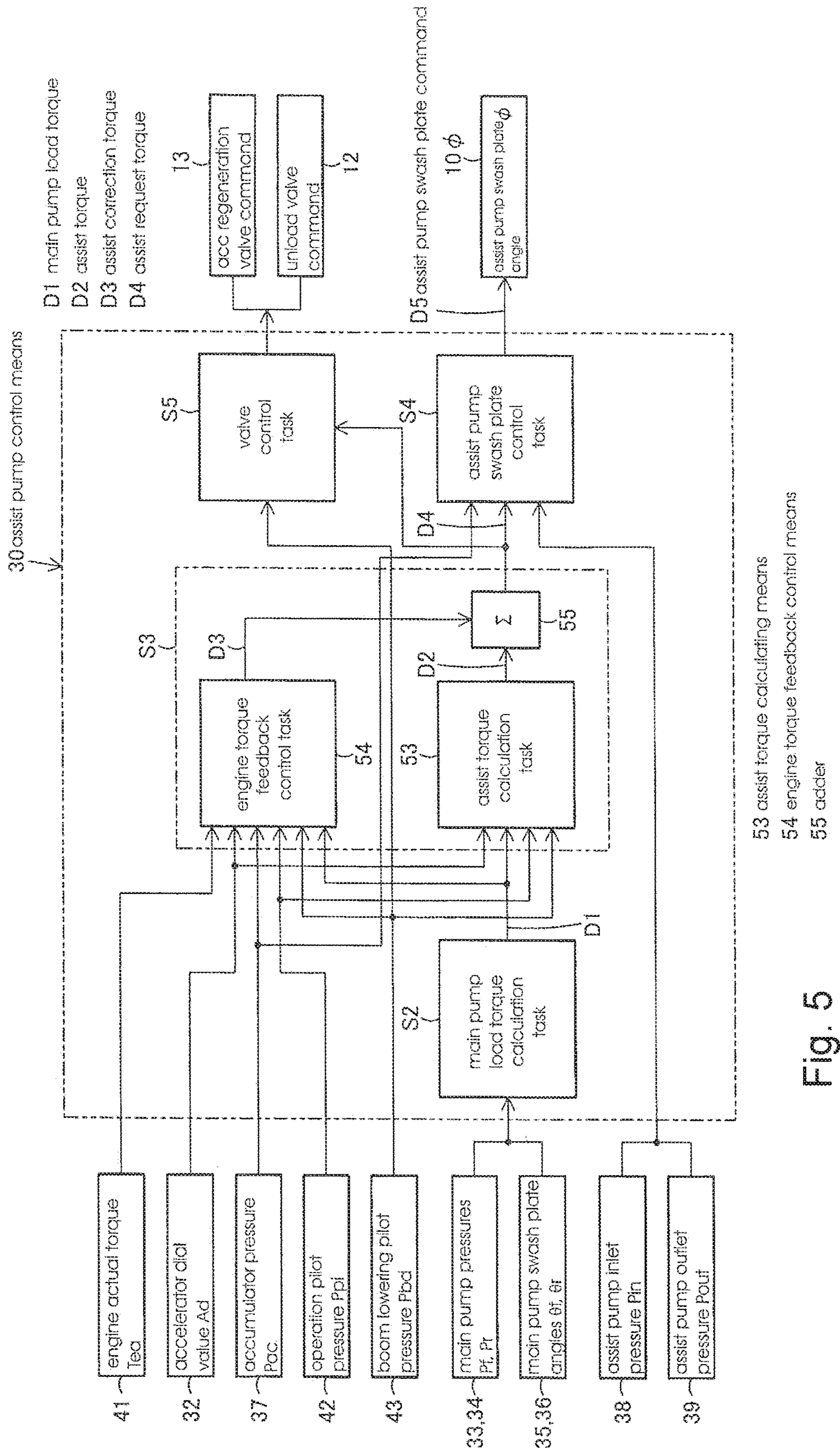


Fig. 4





53 assist torque calculating means
54 engine torque feedback control means
55 adder

Fig. 5

Fig. 6

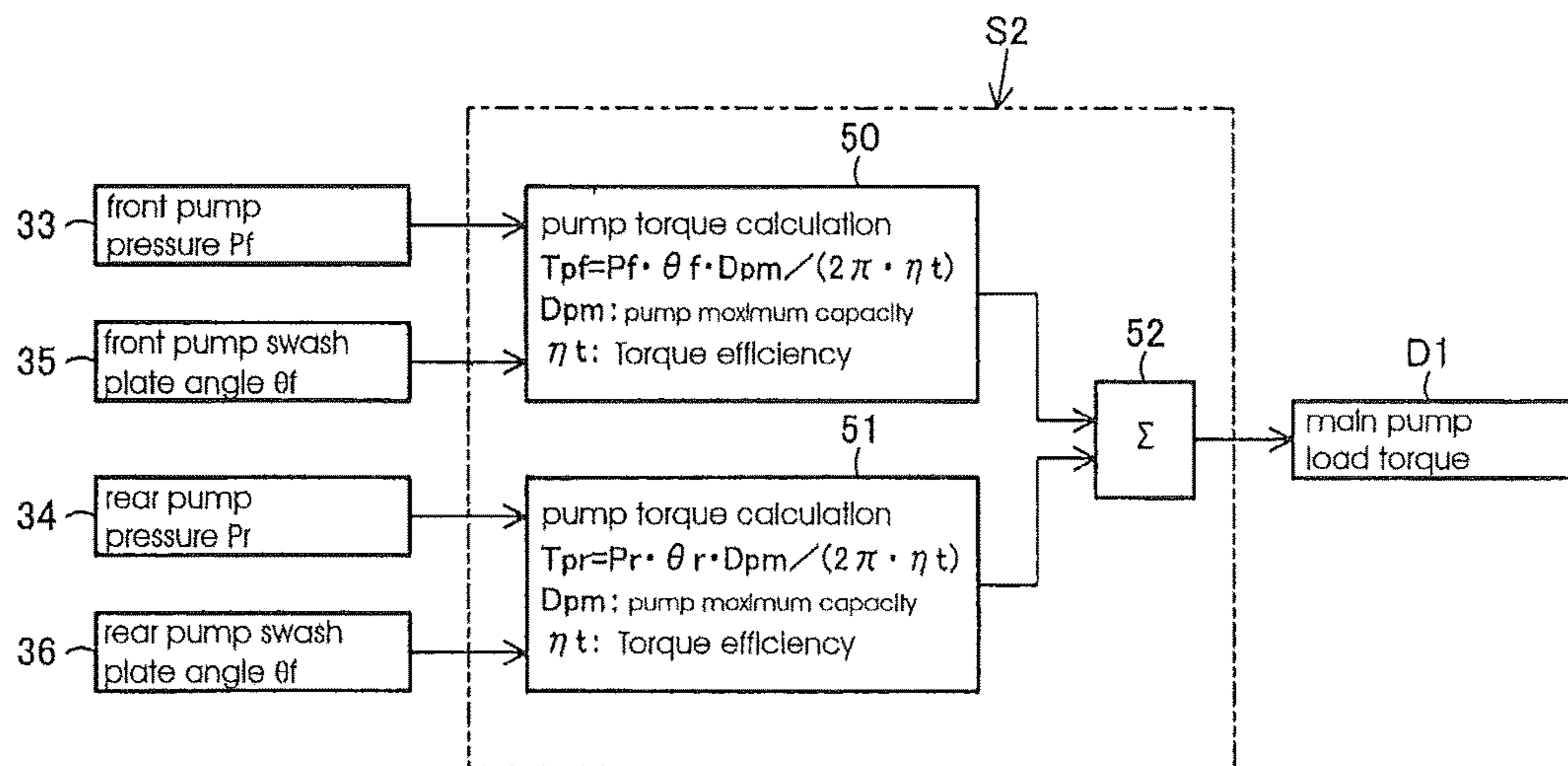


Fig. 7

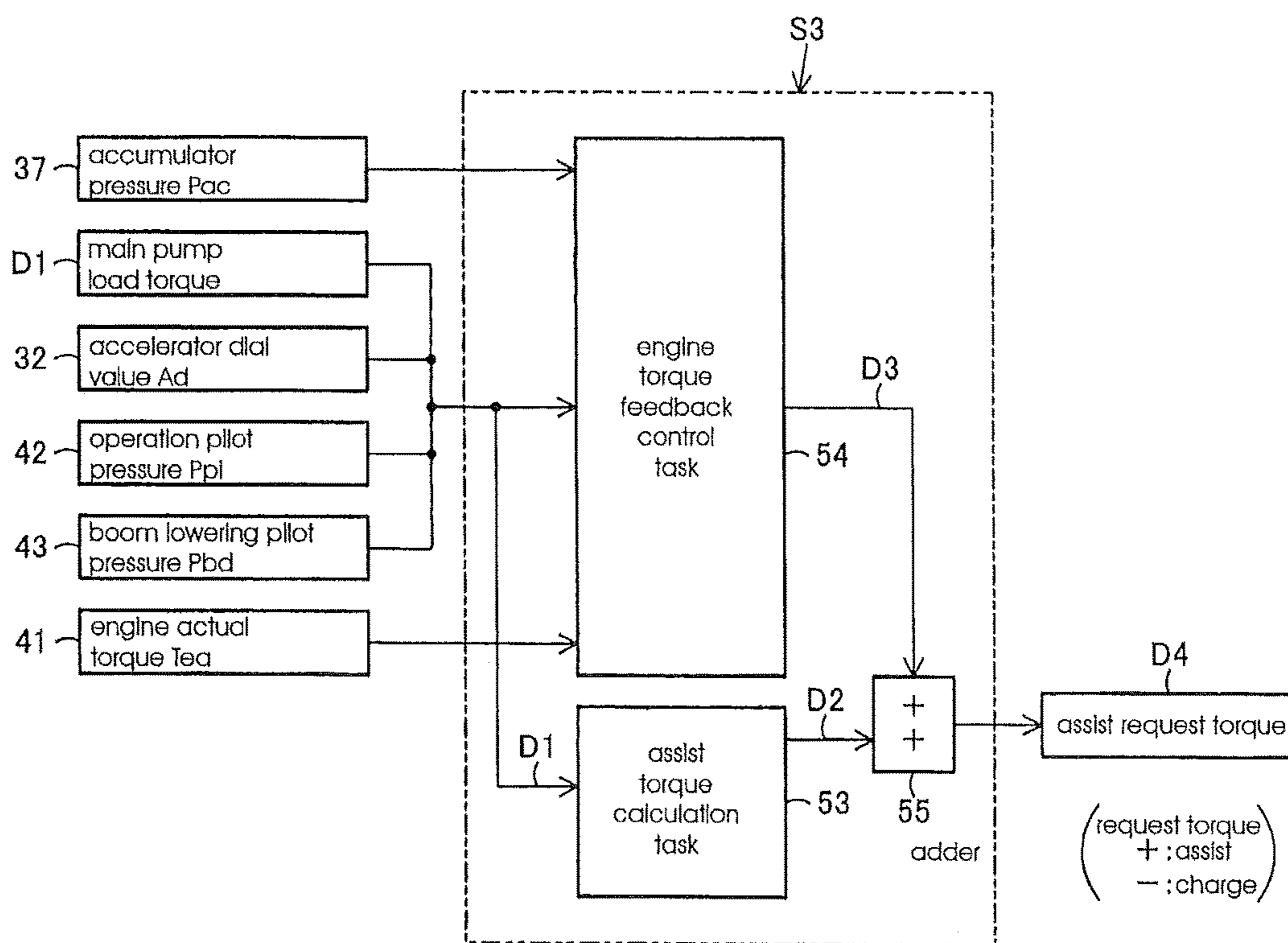


Fig. 8

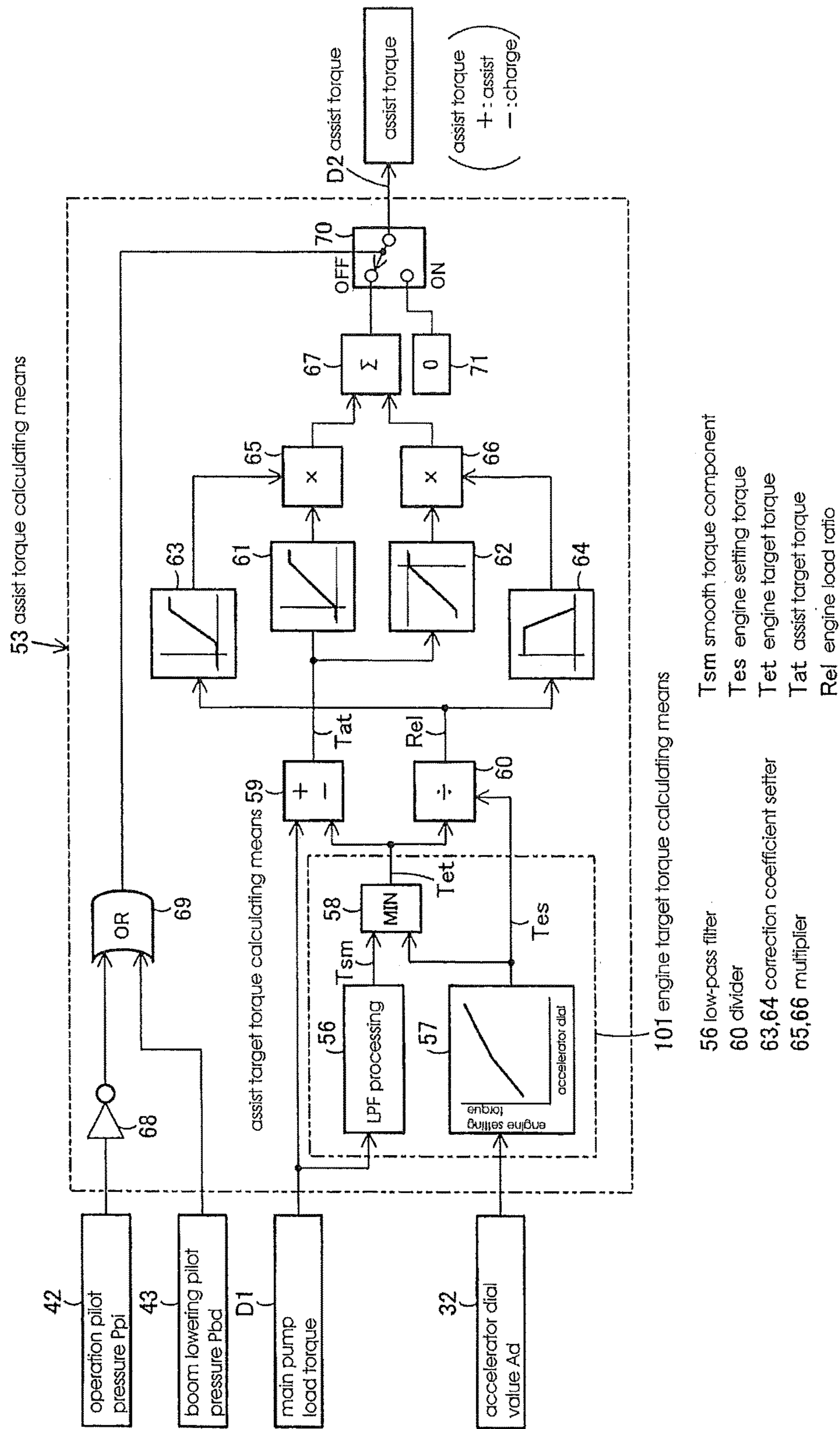


Fig. 9

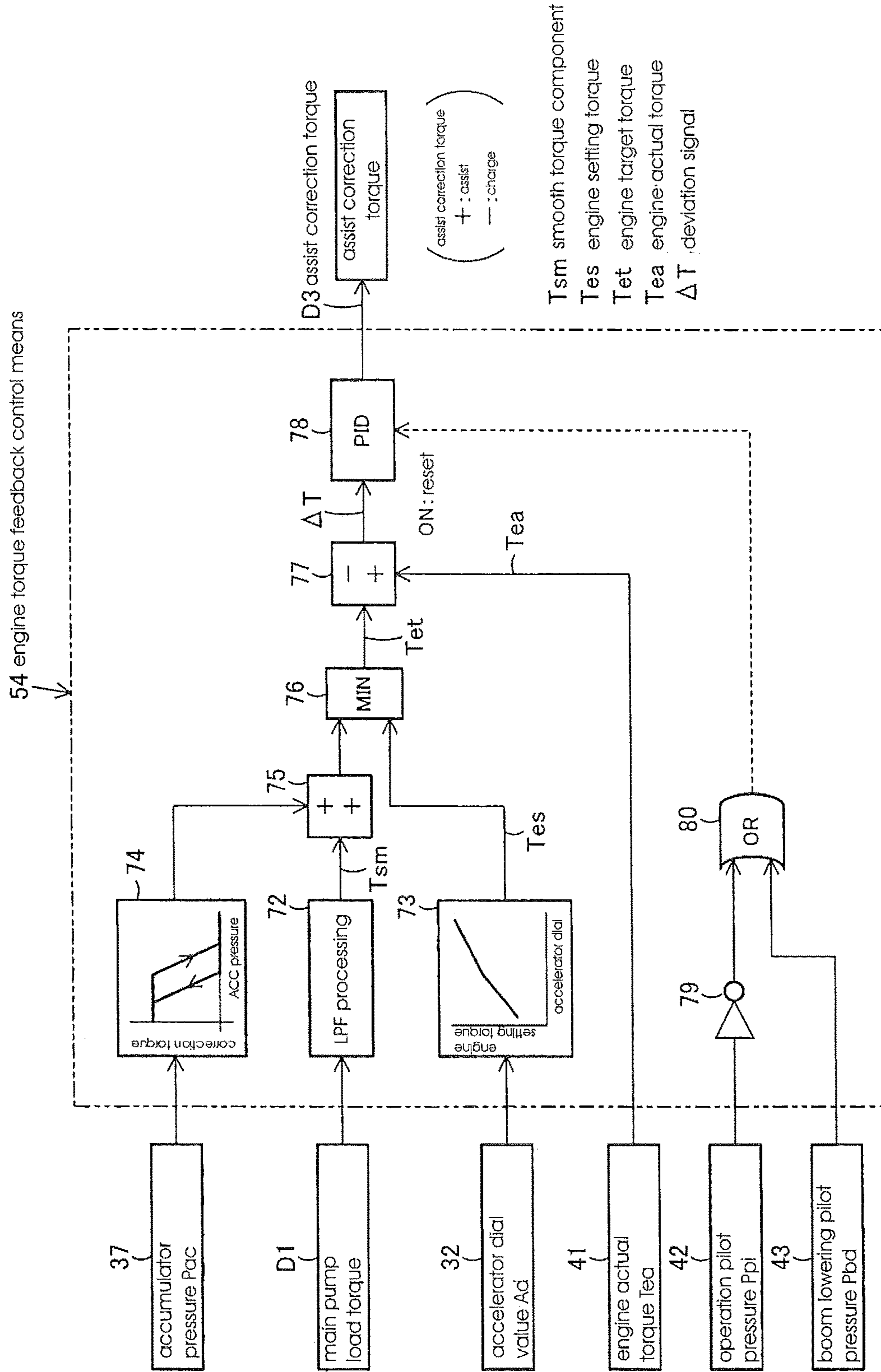


Fig. 10

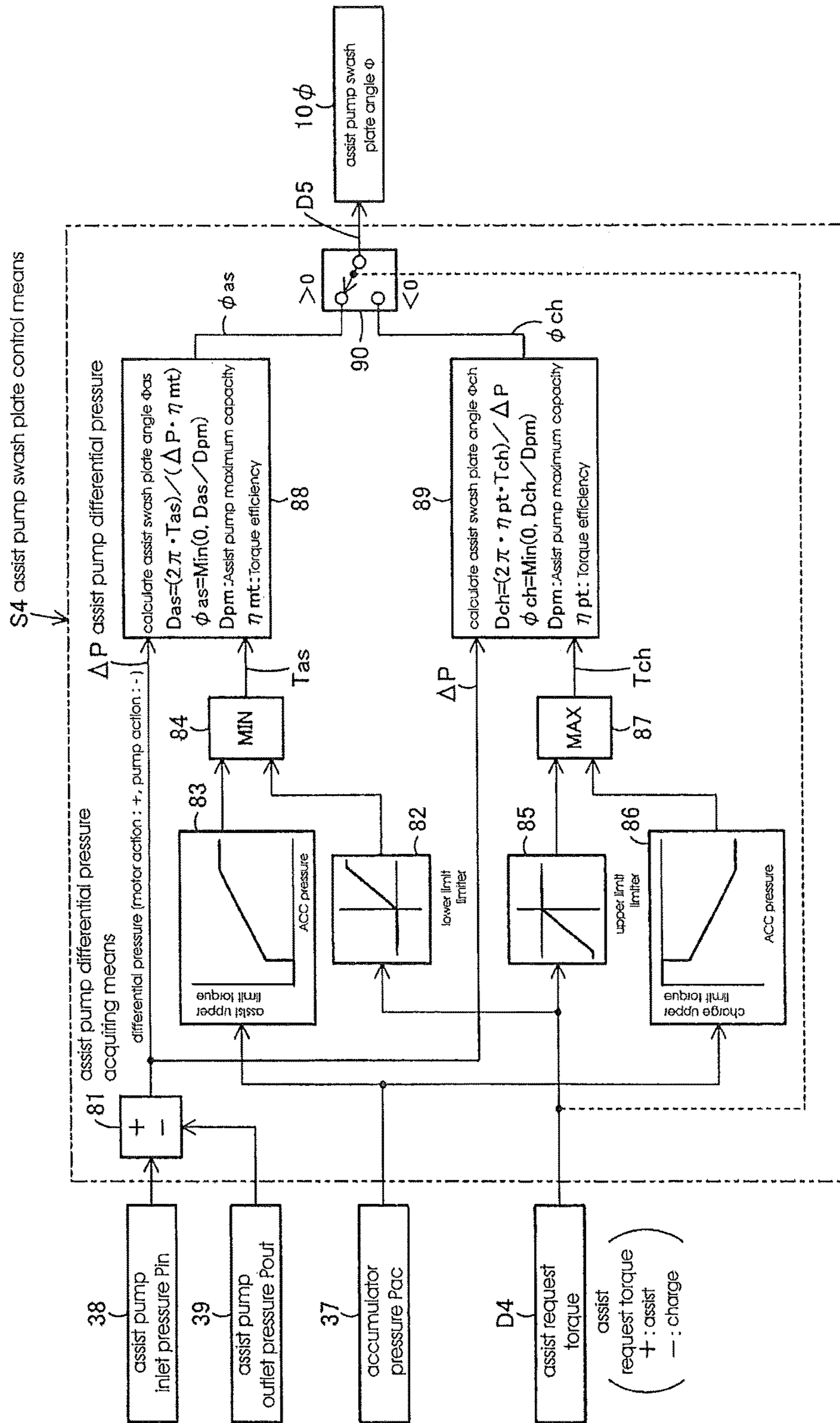


Fig. 11

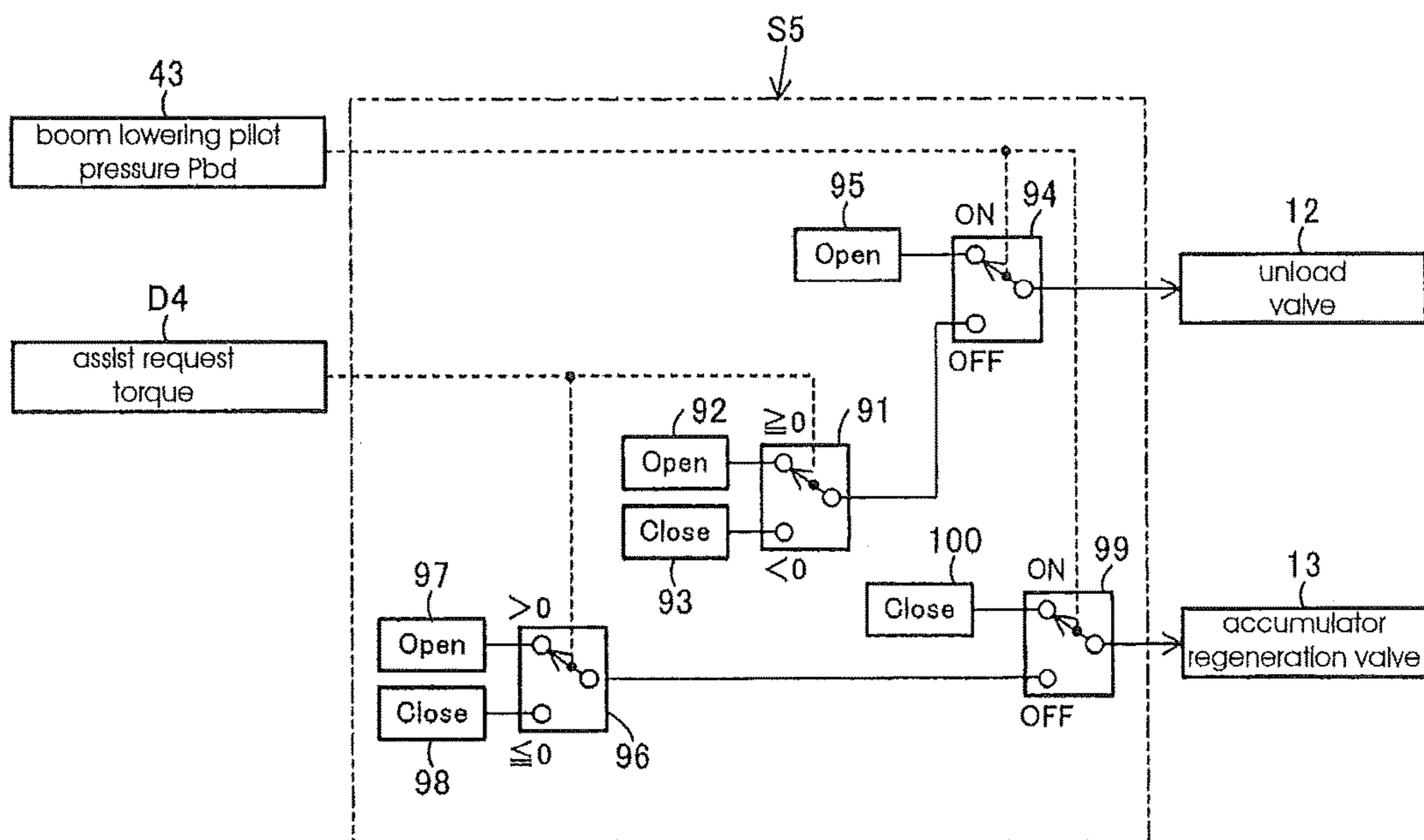


Fig. 12

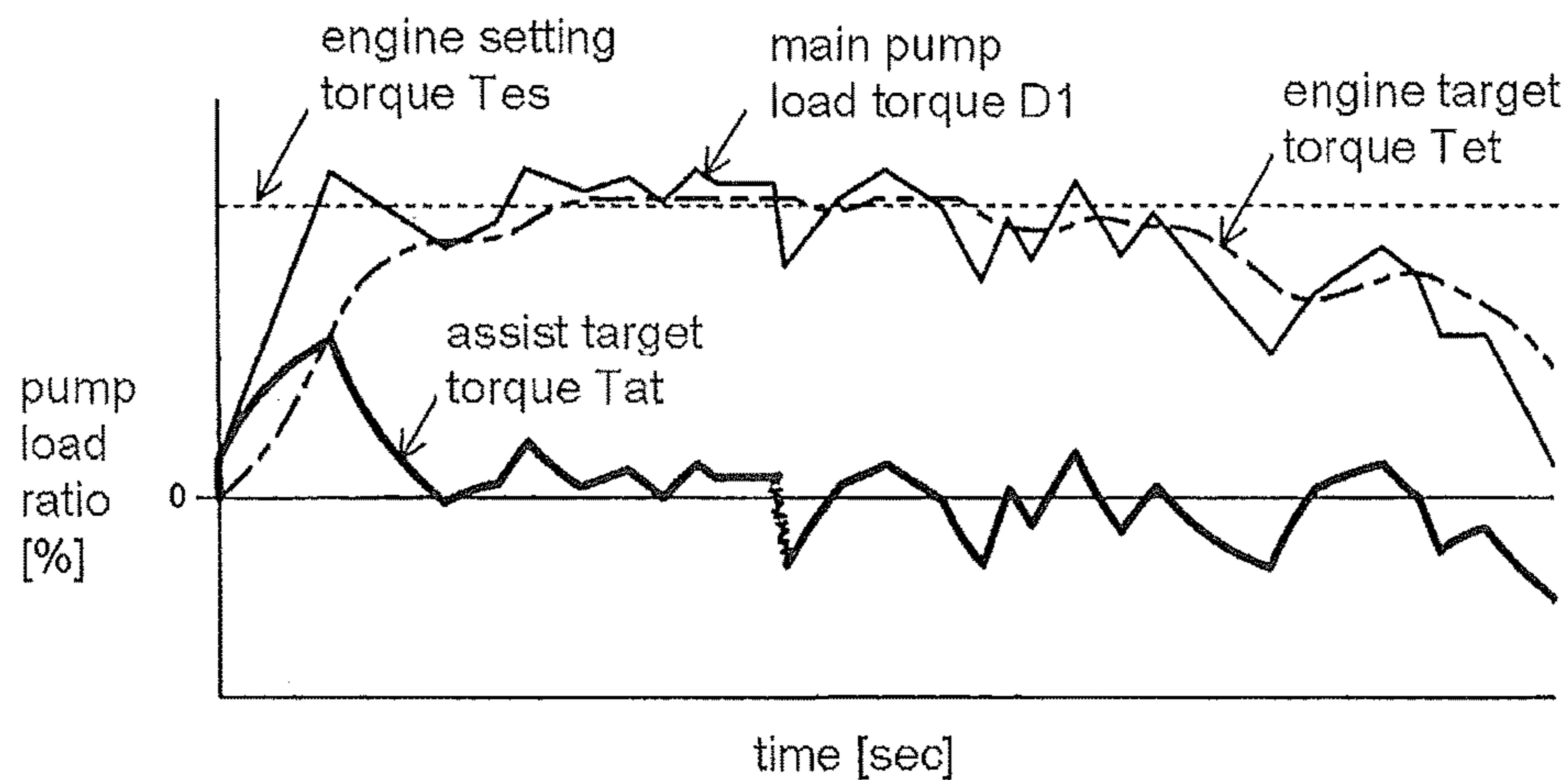


Fig. 13

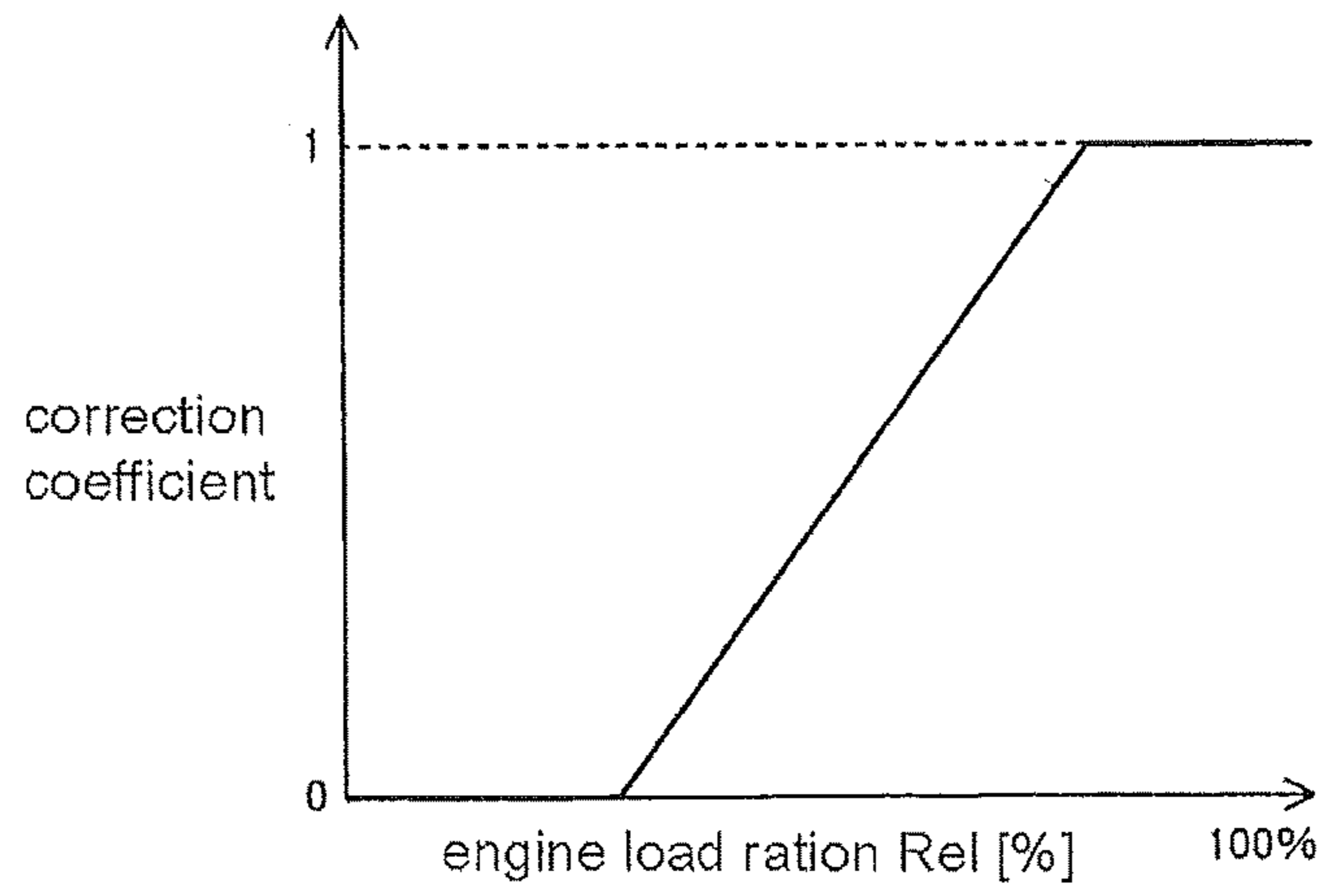


Fig. 14

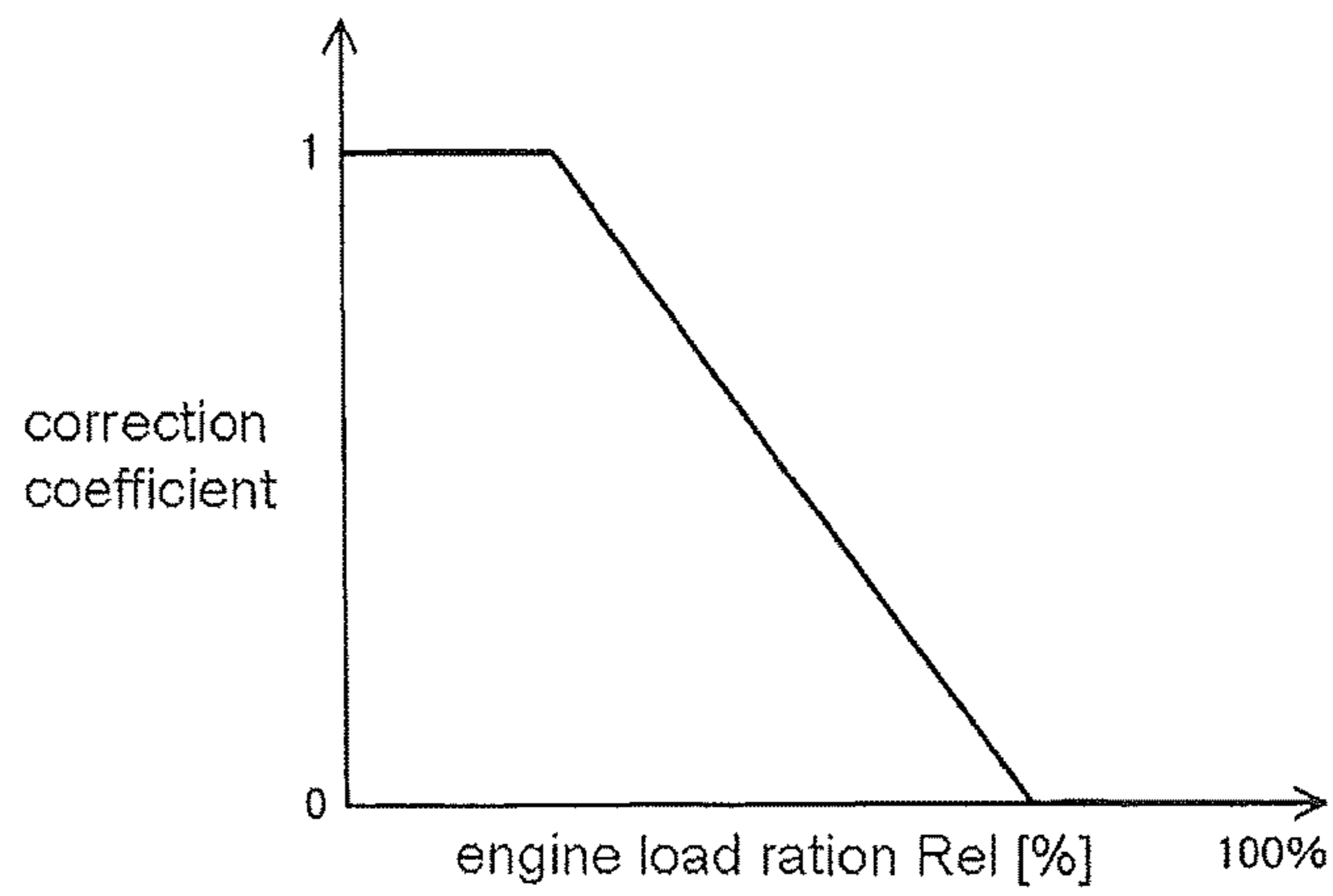


Fig. 15

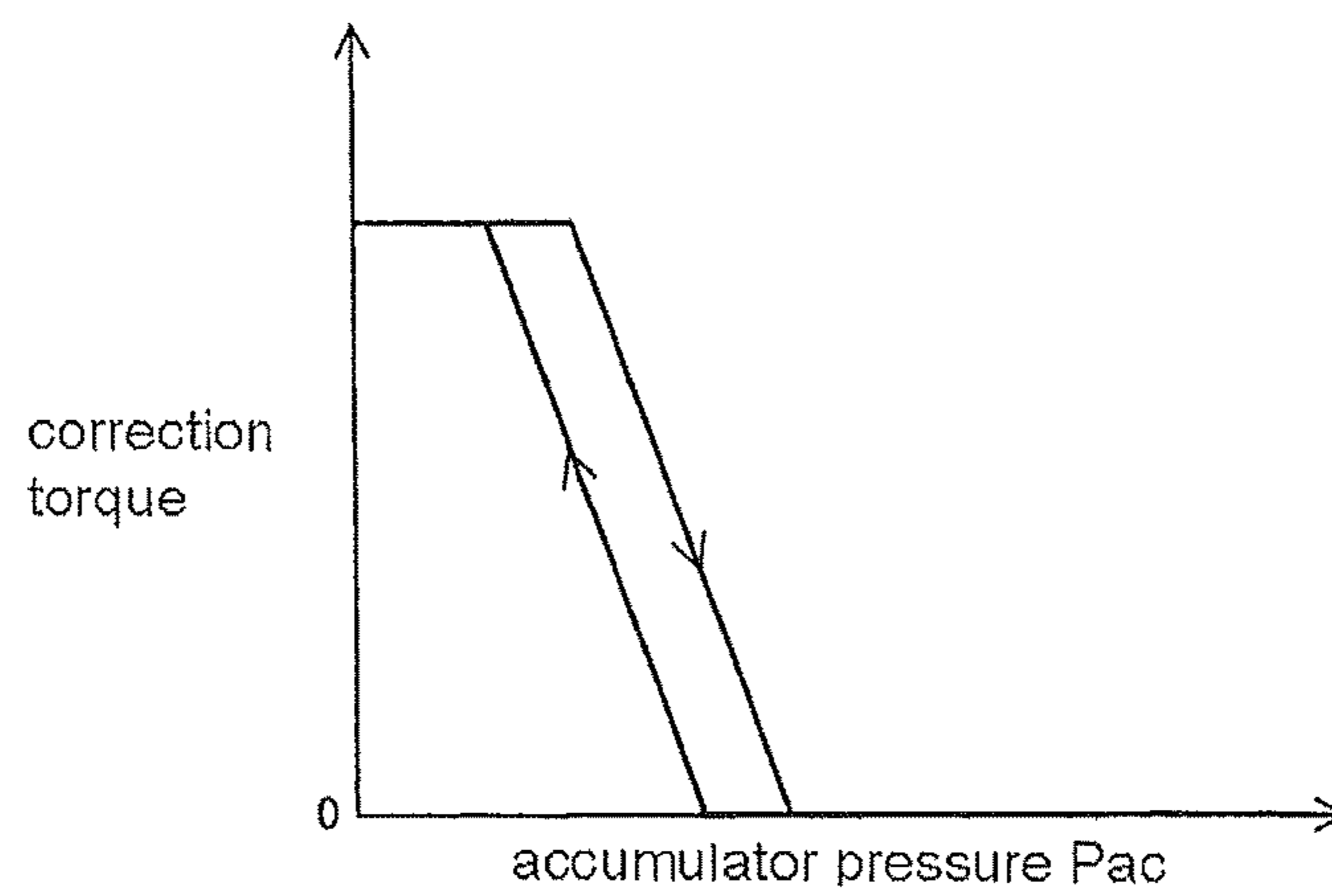


Fig. 16

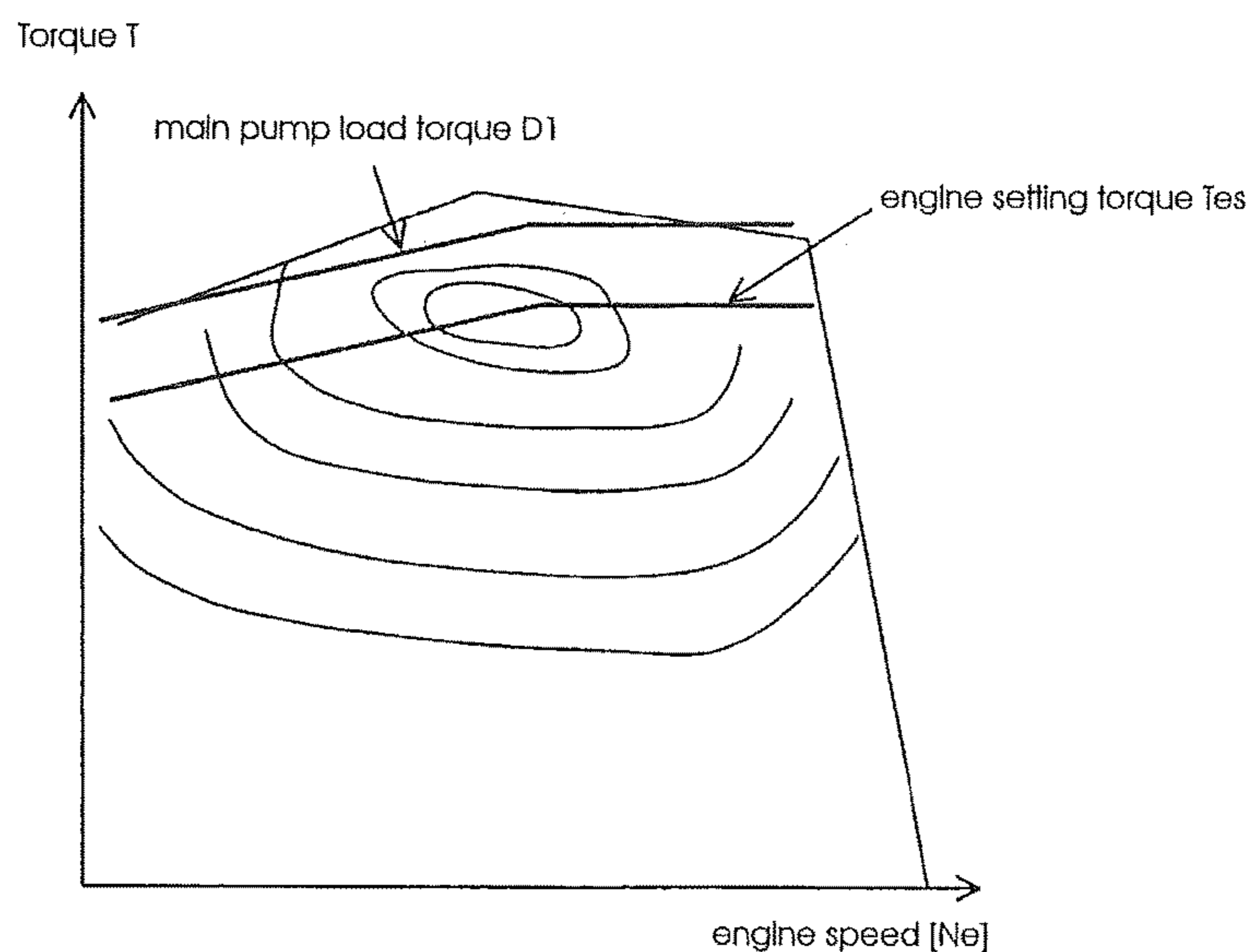
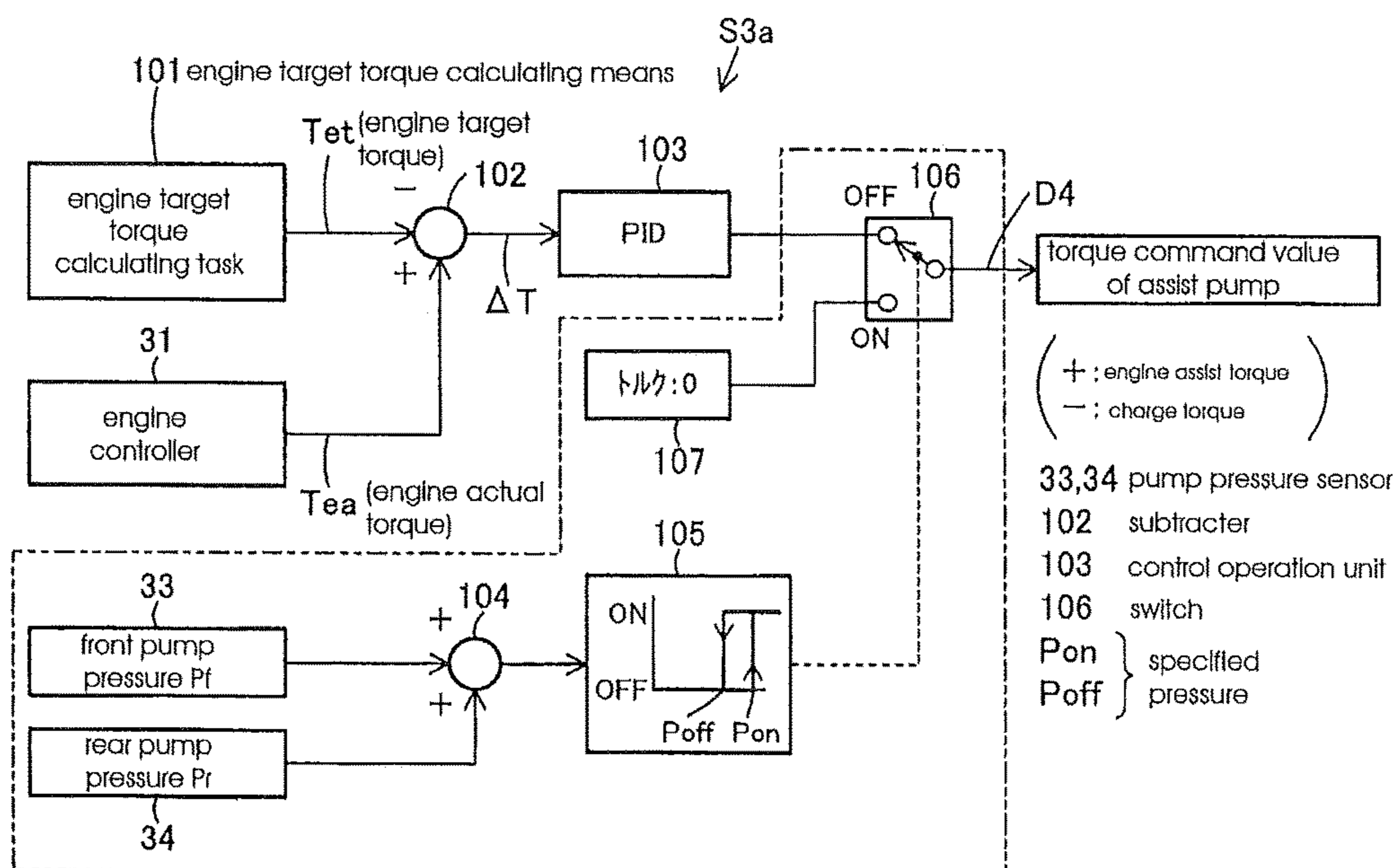


Fig. 17



1**CONTROL DEVICE AND WORKING
MACHINE****CROSS-REFERENCE TO RELATED
APPLICATIONS**

This application is a national phase application of International Patent Application No. PCT/EP2015/058433, filed Apr. 17, 2015, which claims priority to Japanese Patent Application No. JP 2014-086638, filed Apr. 18, 2014, both of which are incorporated by reference herein in their entireties for all purposes.

TECHNICAL FIELD

The present invention relates to a control device including an assist pump and an accumulator and a working machine mounted with the control device.

BACKGROUND ART

As an example of an energy regeneration system in a working machine hydraulically driven such as a hydraulic shovel, there is a system in which a fluid pressure motor such as a variable capacity hydraulic motor is set in-line in a return fluid passage provided between a control valve and a tank, an input shaft of a fluid pressure pump such as a variable capacity hydraulic pump is connected to an output shaft of the fluid pressure motor via reduction gears, a supply port of a direction control valve is communicated with a discharge port of the fluid pressure port via a check valve, and one output port of the direction control valve is connected to an accumulator for pressure accumulation and the other output port is connected to a main pump circuit that supplies working fluid from a main pump to a fluid pressure actuator (see, for example, Patent Document 1).

This system supplies return fluid to the variable capacity hydraulic motor, drives the variable capacity hydraulic pump to accumulate pressure in the accumulator, supplies pressure oil of the accumulator to the main pump during actuator actuation, and regenerates energy.

There is a power regenerating mechanism that increases pressure of the pressurized oil discharged from a head end of a boom cylinder with a pump motor and accumulates the pressurized oil in an accumulator during boom lowering of a hydraulic shovel, accumulates the pressurized oil released from a swing motor driving circuit in the accumulator during acceleration and deceleration of swing, and, when the accumulator is in a saturated state, guides the pressurized oil to the pump motor and causes the pump motor to perform motor operation, to assist engine power (see, for example, Patent Document 2).

Besides, in recent years, in a working machine such as a hydraulic shovel, a hybrid system obtained by combining a hydraulic system and an electric system has been attempted. For example, a generator motor is provided in an engine driving unit, the generator motor is adopted for swing driving, an upper swing body is driven by the generator motor and brake energy is converted into electricity to charge a capacitor and/or a battery during swing braking, and accumulated electric power is used for the swing driving. The capacitor or battery is charged by the generator motor directly connected to the engine during light engine load and power assist is performed by the generator motor using the charged electric power during heavy load.

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Patent Document 1: Japanese Patent Application Laid-open No. 2006-322578

Patent Document 2: Japanese Patent Application Laid-open No. 2010-084888

DISCLOSURE OF THE INVENTION

Problems of the conventional techniques are summarized below.

In the energy regenerating system including the accumulator described in Patent Document 1 and Patent Document 2, when the pressurized oil which is accumulated in the accumulator is supplied to the hydraulic actuator, amount of the pressurized oil supplied from the accumulator may fluctuate as hydraulic status of the main pump circuit or the other reason. Therefore, stable energy regeneration cannot be performed.

On the other hand, in the hybrid system obtained by combining the hydraulic system and the electric system, large-capacity generator motor, capacitor and battery, and electric control devices that perform electric control of those generator motor, capacitor, and battery are necessary so that cost of the machine is higher. Further, there is a problem in that the hybrid system cannot be mounted on a conventional machine through simple rework.

The present invention has been devised in view of such points and it is an object of the present invention to provide a small and inexpensive control device that can effectively suppress load fluctuation of an engine according to a state of a main pump circuit, for example, and a working machine mounted with the control device.

An invention described in claim 1 is a control device including: a main pump driven by an engine and supplying hydraulic oil to a hydraulic circuit; a variable capacity assist pump coupled to an engine or a main pump and having both functions of a pump and a motor; an accumulator provided to be able to communicate with the assist pump and accumulate hydraulic energy; accelerator means for inputting engine setting torque; engine actual torque acquiring means for detecting or calculating engine actual torque; engine control means for controlling the engine actual torque; and assist pump control means for controlling the capacity of the assist pump and switching between an assist mode for assisting the engine with the motor function of the assist pump and a charge mode for accumulating pressure in the accumulator with the pump function of the assist pump, wherein the assist pump control means includes: main pump load torque calculating means for calculating main pump load torque applied to the main pump; engine target torque calculating means for separating a smooth torque component from the main pump load torque and setting a minimum of the smooth torque component and the engine setting torque, as engine target torque; assist target torque calculating means for calculating assist target torque from a difference between the main pump load torque and the engine target torque; and a function for controlling the capacity of the assist pump and controlling the switching of the assist mode and the charge mode on the basis of the assist target torque.

An invention described in claim 2 is the control device according to claim 1, wherein the assist pump includes: a swash plate for variably adjusting a pump capacity; and a swash plate angle adjusting unit that adjusts an angle of the assist pump swash plate, the assist pump control means includes: accumulator pressure detecting means for detecting accumulator pressure of the accumulator; assist pump differential pressure acquiring means for detecting inlet pressure and outlet pressure of the assist pump and thereby calculating assist pump differential pressure; assist torque calculating means for multiplying the assist target torque

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with an engine load ratio, which is calculated by dividing the engine target torque by the engine setting torque, to obtain assist torque as feed-forward torque; engine torque feedback control means for calculating assist correction torque on the basis of a deviation signal obtained by feeding back the engine actual torque to the engine target torque; an adder that adds up the assist torque calculated by the assist torque calculating means and the assist correction torque calculated by the engine torque feedback control means thereby obtaining assist request torque; and assist pump swash plate control means for receiving inputs of the assist request torque, the accumulator pressure, and the assist pump differential pressure to calculate an assist pump swash plate angle, thereby outputting an assist pump swash plate command and controlling the assist pump swash plate angle to smooth the engine actual torque.

An invention described in claim 3 is the control device according to claim 2, wherein the assist torque calculating means includes: a divider that divides the engine target torque by the engine setting torque to calculate the engine load ratio; a correction coefficient setter that adjusts the assist torque to increase when the engine load ratio is high and adjusts the charge torque to increase when the engine load ratio is low; and a multiplier that multiplies the assist target torque with an output of the correction coefficient setter to correct the assist target torque.

An invention described in claim 4 is a control device including: a main pump driven by an engine and supplying hydraulic oil to a hydraulic circuit; a variable capacity assist pump coupled to an engine or a main pump and having both functions of a pump and a motor; an accumulator provided be capable of connecting with the assist pump to accumulate hydraulic energy; accelerator means for inputting engine setting torque; engine actual torque acquiring means for detecting or calculating engine actual torque; engine control means for controlling the engine actual torque; and assist pump control means for controlling the capacity of the assist pump and switching between an assist mode for assisting the engine with the motor function of the assist pump and a charge mode for accumulating pressure in the accumulator with the pump function of the assist pump, wherein the assist pump control means includes: main pump load torque calculating means for calculating main pump load torque applied to the main pump; engine target torque calculating means for separating a smooth torque component from the main pump load torque and setting a minimum of the smooth torque component and the engine setting torque as engine target torque; a subtracter that calculates a deviation between the engine target torque and the engine actual torque; a control, operation unit that subjects an output of the subtracter to PID operation processing to obtain a torque command value of the assist pump; a pump pressure sensor that detects main pump pressure; a switch that implements switching to set the torque command value of the assist pump to zero when the main pump pressure is higher than specified pressure, and select an output of the control operation unit and set the output as the torque command value of the assist pump when the main pump pressure is lower than the specified pressure; and a function for controlling the capacity of the assist pump on the basis of the torque command value and controlling the switching of the assist mode and the charge mode.

An invention described in claim 5 is a working machine including: a machine body hydraulically driven; a working device mounted on the machine body; and the control device described in any one of claims 1 to 4 provided for the machine body and the working device, wherein the accu-

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mulator of the control device includes a function of accumulating and discharging brake energy of the machine body and position energy of the working device.

According to the invention described in claim 1, the smooth torque component is separated from the main pump load torque and the minimum of the smooth torque component and the engine setting torque is set as the engine target torque by the engine target torque calculating means. The assist target torque is calculated from the difference between the main pump torque and the engine target torque by the assist target torque calculating means. The capacity of the assist pump and the switching of the assist mode of the engine and the charge mode of the accumulator are controlled by the assist pump control means on the basis of the assist target torque. It is possible to smooth the engine target torque by absorbing load fluctuation with the assist pump control means having high responsiveness to a torque request that frequently changes. It is possible to smoothly change the engine actual torque according to the engine target torque. Since a large-capacity generator motor, battery, or the like is unnecessary, it is possible to provide a small and inexpensive control device that can effectively suppress load fluctuation of the engine according to, for example, a state of the main pump circuit. In particular, the engine target torque calculating means sets the minimum of the smooth torque component, which is separated from the main pump load torque, and the engine setting torque as the engine target torque. Therefore, when the pressure of the accumulator decreases, control is performed to gradually increase the engine target torque to perform charging. Therefore, it is possible to more flatly change the engine target torque smoothed by the engine setting torque. It is possible to effectively suppress load fluctuation of the engine. It is also possible to attain suppression of exhaust gas and a reduction in the sizes of the engine and a post processing device.

According to the invention described in claim 2, the assist target torque is multiplied with the engine load ratio calculated by dividing the engine target torque by the engine setting torque to calculate the assist torque as the feed-forward torque. The assist correction torque is calculated on the basis of the deviation signal obtained by feeding back the engine actual torque to the engine target torque. The assist torque and the assist correction torque are added up to calculate the assist request torque. Therefore, according to the accurate assist request torque corrected by the engine load ratio and the engine actual torque, it is possible to output an accurate assist pump swash plate command to the assist pump that variably adjusts the pump capacity according to the assist pump swash plate angle.

According to the invention described in claim 3, the engine target torque is divided by the engine setting torque to calculate the engine load ratio. The assist target torque is corrected to increase the assist torque when the engine load ratio is high and increase the charge torque when the engine load ratio is low. Therefore, it is possible to appropriately adjust the assist target torque according to a load state of the engine.

According to the invention described in claim 4, the smooth torque component is separated from the main pump load torque and the minimum of the smooth torque component and the engine setting torque is set as the engine target torque by the engine target torque calculating means. The deviation between the engine target torque and the engine actual torque is subjected to the PID control to calculate the torque command value of the assist pump. The capacity of the assist pump and the switching of the assist mode of the

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engine and the charge mode of the accumulator are controlled on the basis of the torque command value. It is possible to smooth the engine target torque by absorbing load fluctuation with the assist pump control means having high responsiveness to a torque request that frequently changes. It is possible to smoothly change the engine actual torque according to the engine target torque. Moreover, since a large-capacity generator motor, battery, or the like is unnecessary, it is possible to provide a small and inexpensive control device that can effectively suppress load fluctuation of the engine according to, for example, a state of the main pump circuit. Further, the switching is performed by the switch to set the torque command value of the assist pump to zero when the main pump pressure is higher than the specified pressure, and set the output of the control operation unit as the torque command value of the assist pump when the main pump pressure is lower than the specified pressure. Therefore, in the case of a relief state in which the main pump pressure is higher than the specified pressure, the torque command value of the assist pump is set to zero to stop the assist of the engine and, when the main pump pressure is lower than the specified pressure, the assist of the engine is resumed. Therefore, it is possible to prevent useless consumption of energy accumulated by the accumulator.

According to the invention described in claim 5, when the machine body and the working device are actuated in the working machine hydraulically driven, the brake energy and the position energy of the working machine can be effectively used by the accumulator of the control device including the function of accumulating and discharging the brake energy of the machine body and the position energy of the working machine. It is possible to effectively suppress load fluctuation of the engine. It is possible to attain suppression of exhaust gas and a reduction in the sizes of the engine and a post processing device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a circuit diagram showing an embodiment of a control device according to the present invention.

FIG. 2 is a side view of a working machine mounted with the control device.

FIG. 3 is a block diagram showing an input/output relation of the control device.

FIG. 4 is a flowchart for explaining a control flow of the control device.

FIG. 5 is a control block diagram showing a relation among tasks of the control device.

FIG. 6 is a calculation block diagram showing a main pump load torque calculation task of the control device.

FIG. 7 is a calculation block diagram showing an assist request torque calculation task of the control device.

FIG. 8 is a calculation block diagram showing an assist torque calculation task of the control device.

FIG. 9 is a calculation block diagram showing an engine torque feedback control task of the control device.

FIG. 10 is a calculation block diagram showing an assist pump swash plate control task of the control device.

FIG. 11 is a calculation block diagram showing a valve control task of the control device.

FIG. 12 is a characteristic chart showing an actual example of engine assist control by the control device.

FIG. 13 is a characteristic chart showing a relation between an engine load ratio and a correction coefficient of an assist correction coefficient setter of the control device.

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FIG. 14 is a characteristic chart showing a relation between an engine load ratio and a correction coefficient of a charge correction coefficient setter of the control device.

FIG. 15 is a characteristic chart of a correction torque table showing a relation between accumulator pressure and correction torque of the control device.

FIG. 16 is a characteristic chart showing a relation between main pump load torque and engine setting torque of the control device.

FIG. 17 is a calculation block diagram showing another embodiment of the control device.

BEST MODE FOR CARRYING OUT THE INVENTION

The present invention is explained in detail below on the basis of an embodiment shown in FIG. 1 to FIG. 16 and another embodiment shown in FIG. 17.

(A System of an Engine Assist Device)

FIG. 2 shows a working machine HE for magnet work in which a hydraulic shovel is a base machine. In the working machine HE, a machine body B is configured by a lower traveling body 1 and an upper swing body 2 turnably provided on the lower traveling body 1. A front working device F functioning as a working device is mounted on the upper swing body 2. In the front working device F, the base end of a boom 3 is pivotally supported by the upper swing body 2 to be rotatable in the up-down direction. An arm 4 is pivotally connected to the tip of the boom 3. An attachment (a lifting magnet) 5 is pivotally connected to the tip of the arm 4. The boom 3 of the front working device F is rotated by a boom cylinder 3a. The arm 4 is rotated by an arm cylinder 4a. The attachment 5 is rotated by a bucket cylinder 5a, which is originally used for bucket rotation.

FIG. 1 shows the configuration of mainly a hydraulic system of a control device C provided for the machine body B and the front working device F. In FIG. 1, a front pump 7 and a rear pump 8 functioning as main pumps (these pumps are hereinafter referred to as main pumps 7 and 8) driven by an engine 6 mounted on the upper swing body 2 and a part (a boom cylinder 3a and a swing motor 9 that drives to turn the upper swing body 2) of a hydraulic actuator that receives supply of hydraulic oil from the main pumps 7 and 8 are shown.

A main pump circuit (not shown in the figure) that controls, with a control valve (not shown in the figure), the direction of the hydraulic oil discharged from the main pumps 7 and 8 and supplies the hydraulic oil to various hydraulic actuators such as the boom cylinder 3a, the arm cylinder 4a, the bucket cylinder 5a, the swing motor 9, and a traveling motor (not shown in the figure) is connected to discharge ports of the main pumps 7 and 8.

A variable capacity assist pump 10 having both functions of a pump and a motor is coupled to the engine 6 or the main pumps 7 and 8. In a passage where the pressure oil discharged from the assist pump 10 and the pressure oil discharged from the boom cylinder 3a and the swing motor 9 merge, an accumulator 11 that accumulates the pressure of the pressure oils to accumulate energy is provided.

A passage on an outlet side of the assist pump 10 is connected to an unload valve 12 capable of opening the passage on the outlet side to a tank 23. In a passage through which the accumulator 11 and an inlet side of the assist pump 10 can communicate with each other, an accumulator regeneration valve 13 for supplying the pressure oil accumulated (charged) in the accumulator 11 to the inlet side of the assist pump 10 is provided. The unload valve 12 and the

accumulator regeneration valve **13** are electromagnetic valves opened and closed according to on/off electric signals.

In a passage between a head end of the boom cylinder **3a** and the accumulator **11**, a boom regeneration valve **14** that can supply the pressure oil in a head chamber of the boom cylinder **3a** to the accumulator **11** by being switched by not-shown boom lowering pilot pressure is provided. The boom regeneration valve **14** is an on/off valve pilot-operated by pilot pressure from an electromagnetic valve (not shown in the figure).

A high-pressure selection valve **15** configured by a pair of check valves is provided between left and right ports of the swing motor **9**. A sequence valve **16** and a check valve **24** for accumulating pressure in the accumulator **11** while keeping brake pressure are provided in a passage drawn out from between the check valves of the high-pressure selection valve **15**.

The main pumps **7** and **8** include variable capacity swash plates and adjust swash plate angles with swash plate angle adjusting units **7 θ** and **8 θ** such as pump regulators to variably control pump capacities. An output circuit of an electromagnetic proportional valve for power shift **17** is connected to the swash plate angle adjusting units **7 θ** and **8 θ** . The electromagnetic proportional valve for power shift **17** outputs hydraulic pressure proportional to an input electric signal to the swash plate angle adjusting units **7 θ** and **8 θ** and variably controls the pump capacities to adjust the torque of the main pumps **7** and **8**.

The assist pump **10** includes a variable capacity swash plate and adjusts a swash plate angle with a swash plate angle adjusting unit **10 ϕ** to thereby variably control a pump capacity or a motor capacity. The swash plate angle adjusting unit **10 ϕ** proportionally operates according to an electric signal.

A check valve **18** is provided in a passage between the head end of the boom cylinder **3a** and the boom regeneration valve **14**. A check valve **19** is provided in a passage between the boom regeneration valve **14** and the inlet side of the assist pump **10**. A check valve **20** is provided in a passage between the boom regeneration valve **14** and the accumulator **11**. A check valve **21** is provided in a passage between the outlet side of the assist pump **10** and the accumulator **11**. A check valve **22** is provided in a passage for supplying oil from the tank **23** to the inlet side of the assist pump **10**. A backflow is prevented by the check valves **18** to **22**.

Reference numeral **30** denotes a machine controller functioning as assist pump control means for controlling an engine assist system. An engine controller **31** functioning as engine control means for controlling the engine **6** is connected to the machine controller **30** to enable bidirectional communication.

An accelerator dial **32** functioning as accelerator means for setting engine speed and engine setting torque, pump pressure sensors **33** and **34** that detect discharge pressures of the main pumps **7** and **8**, pump swash plate angle sensors **35** and **36** that detect swash plate angles of the main pumps **7** and **8**, an accumulator pressure sensor **37** functioning as accumulator pressure detecting means for detecting accumulator pressure **Pac** of the accumulator **11**, and an assist pump inlet pressure sensor **38** and an assist pump outlet pressure sensor **39** that detect pressures of the inlet and the outlet of the assist pump **10** are connected to an input side of the machine controller **30**.

An engine speed sensor **40** that detects engine actual speed **Ne** and an engine torque sensor **41** functioning as engine actual torque acquiring means for detecting engine

actual torque **Tea** are connected to the input side of the engine controller **31**. Note that the engine actual torque acquiring means is not limited to the torque sensor **41** and also includes calculating means for estimating, with the engine controller **31**, the engine actual torque **Tea** from a fuel injection amount, intake pressure, and the like of the engine **6**.

An output side of the engine controller **31** is connected to a fuel injection device of a fuel supply system and control units of an air intake and exhaust system, a start control system, and the like of the engine **6**. The engine controller **31** electronically controls fuel injection timing, a fuel injection amount, and the like of the fuel injection device and controls the engine actual torque **Tea** according to engine target torque **Tet** explained below.

An operation pilot pressure sensor **42** that detects operation pilot pressure **Ppi** (excluding boom lowering pilot pressure) for pilot-operating spools of a control valve (not shown in the figure), which controls various hydraulic actuators of the working machine **HE**, to detect an operation state of the working machine **HE** and a boom lowering pilot pressure sensor **43** that detects boom lowering pilot pressure **Pbd** for pilot-operating the boom cylinder **3a** in a contracting direction are connected to the input side of the machine controller **30**.

The output side of the machine controller **30** is connected to the electromagnetic proportional valve for power shift **17** that controls the swash plate angle adjusting units **7 θ** and **8 θ** of the main pumps **7** and **8**, the swash plate angle adjusting unit **10 ϕ** that controls an assist pump swash plate angle ϕ when the swash plate of the assist pump **10** is subjected to angle adjustment, solenoids of the unload valve **12** and the accumulator regeneration valve **13**, and an electromagnetic valve for pilot operation (not shown in the figure) of the boom regeneration valve **14**.

The machine controller **30** includes a function for controlling the assist pump swash plate angle ϕ to control a pump capacity of the assist pump **10** and controlling the unload valve **12** and the accumulator regeneration valve **13** to switch an assist mode for assigning the engine **6** with the motor function of the assist pump **10** and a charge mode for accumulating pressure in accumulator **11** with the pump function of the assist pump **10**.

FIG. **3** is a diagram summarizing input/output signals of the control device **C**.

In FIG. **3**, to the machine controller **30**, a set accelerator dial value **Ad** is input from the accelerator dial **32** for setting engine speed, front pump pressure **Pf** and rear pump pressure **Pr** serving as main pump pressures are input from the pump pressure sensors **33** and **34**, a front pump swash plate angle θ_f and a rear pump swash plate angle θ_r are input from the pump swash plate angle sensors **35** and **36**, accumulator pressure **Pac** is input from the accumulator pressure sensor **37**, pump inlet pressure **Pin** is input from the assist pump inlet pressure sensor **38**, assist pump outlet pressure **Pout** is input from the assist pump outlet pressure sensor **39**, the operation pilot pressure **Ppi** is input from the operation pilot pressure sensor **42**, and the boom lowering pilot pressure **Pbd** is input from the boom lowering pilot pressure sensor **43**.

To the engine controller **31**, the engine actual speed **Ne** is input from the engine speed sensor **40** and the engine actual torque **Tea** is input from the engine torque sensor **41**. Further, data of the engine actual speed **Ne** and the engine actual torque **Tea** are sent from the engine controller **31** to the machine controller **30**. Engine setting speed **D6** corre-

sponding to the accelerator dial value Ad is sent from the machine controller 30 to the engine controller 31.

On the other hand, from the machine controller 30, a control signal concerning the assist pump swash plate angle ϕ is output to the swash plate angle adjusting unit 10 ϕ of the assist pump 10, switching signals for the unload valve 12 and the accumulator regeneration valve 13 are output to the unload valve 12 and the accumulator regeneration valve 13, and a control signal for power shift is output to the electro-

magnetic proportional valve for power shift 17. FIG. 4 is a control flowchart, FIG. 5 is a control block diagram showing a relation among calculation tasks shown in FIG. 4, and FIG. 6 to FIG. 11 are calculation block diagrams of the control tasks. The configuration of a control system is explained on the basis of FIG. 4 to FIG. 11.

Note that the torque of the main pumps 7 and 8 is set on the basis of pump setting torque set by the accelerator dial 32 and the operation pilot pressure Ppi determined by an operation amount of operation levers or the like and is controlled via the electromagnetic proportional valve for power shift 17. However, the torque of the main pumps 7 and 8 is not explained because the torque is not directly related to engine assist control. Only components related to the engine assist control are explained.

(1) Explanation of an Entire Control Flowchart

FIG. 4 shows a control flowchart of entire engine assist control.

In an input processing task S1 of the control flowchart, the input signal shown in FIG. 3 is read.

A main pump load torque calculation task S2 functioning as main pump load torque calculation means calculates, as shown in FIG. 5, main pump load torque D1 according to the main pump pressures Pf and Pr detected by the pump pressure sensors 33 and 34 and the main pump swash plate angles θ_f and θ_r detected by the pump swash plate angle sensors 35 and 36. Note that the main pump load torque D1 may be predicted from the operation pilot pressure Ppi and the main pump pressures Pf and Pr.

An assist request torque calculation task S3 calculates, as shown in FIG. 5, assist request torque D4 on the basis of, for example, the main pump load torque D1 output from the main pump load torque calculation task S2.

An assist pump swash plate control task S4 functioning as assist pump swash plate control means calculates, as shown in FIG. 5, an assist pump swash plate command D5 according to the assist request torque D4 output from the assist request torque calculation task S3, the accumulator pressure Pac, and the like.

A valve control task S5 outputs, as shown in FIG. 5, switching signals for the unload valve 12 and the accumulator regeneration valve 13 according to the assist request torque D4 output from the assist request torque calculation task S3 and the boom lowering pilot pressure Pbd.

In short, the assist pump swash plate control task S4 and the valve control task S5 control the capacity (i.e., the assist pump swash plate angle ϕ) of the assist pump 10 and the switching of the assist mode of the engine 6 and the charge mode of the accumulator 11 according to the assist request torque D4 or the like.

The control calculation tasks are explained below.

(2) Main Pump Load Torque Calculation Task S2

FIG. 6 shows calculation blocks of the main pump load torque calculation task S2. The front pump pressure Pf and the rear pump pressure Pr detected by the pump pressure sensors 33 and 34 and the front pump swash plate angle θ_f and the rear pump swash plate angle θ_r detected by the pump

swash plate angle sensors 35 and 36 are input to the main pump load torque calculation task S2.

Pump torque Tpf on a front side is calculated by a pump torque calculation block 50 on the basis of the front pump pressure Pf and the front pump swash plate angle θ_f . Pump torque Tpr on a rear side is calculated by a pump torque calculation block 51 on the basis of the rear pump pressure Pr and the rear pump swash plate angle θ_r . The pump torques Tpf and Tpr on the front side and the rear side are added up by an adder 52 and output as the main pump load torque D1.

The pump torque calculation block 50 on the front side calculates the pump torque Tpf according to the following expressions and outputs the pump torque Tpf.

$$T_{pf} = P_f \theta_f D_{pm} / (2\pi \eta_t)$$

Dpm: Front pump maximum capacity

η_t : Torque efficiency

The pump torque calculation block 51 on the rear side calculates the pump torque Tpr according to the following expression and outputs the pump torque Tpr.

$$T_{pr} = P_r \theta_r D_{pm} / (2\pi \eta_t)$$

Dpm: Rear pump maximum capacity

η_t : Torque efficiency

(3) Assist Request Torque Calculation Task S3

FIG. 7 shows calculation blocks of the assist request torque calculation task S3. In FIG. 7, the accumulator pressure Pac, the accelerator dial 32, the operation pilot pressure Ppi, the boom lowering pilot pressure Pbd, the engine actual torque Tea, and the main pump load torque D1 calculated by the main pump load torque calculation task S2 are input to the assist request torque calculation task S3.

The assist request torque calculation task S3 is configured from an assist torque calculation task 53 functioning as assist torque calculating means and an engine torque feedback control task 54 functioning as engine torque feedback control means. Outputs of both the tasks 53 and 54 are added up by an adder 55 and output as assist request torque D4.

FIG. 8 shows calculation blocks of the assist torque calculation task 53. The assist torque calculation task 53 includes an engine target torque calculation task 101 functioning as engine target torque calculating means including a low-pass filter 56 that applies filter processing to the main pump load torque D1, an engine setting torque table 57 that outputs engine setting torque on the basis of a signal of the accelerator dial 32, and a minimum selection calculator 58 (hereinafter referred to as Min calculator) that compares an output of the low-pass filter 56 and an output of the engine setting torque table 57 and selects a smaller value.

The assist torque calculation task 53 includes a subtracter 59 functioning as assist target torque calculating means for subtracting the engine target torque Tet output from the engine target torque calculation task 101 from the main pump load torque D1 to calculate assist target torque Tat.

The assist torque calculation task 53 separates, with the low-pass filter 56, a smooth torque component Tsm from the main pump load torque D1, calculates, with the Min calculator 58, a minimum of the smooth torque component Tsm and the engine setting torque Tes and sets the minimum as the engine target torque Tet, and subtracts, with the subtracter 59, the engine target torque Tet from the main pump load torque D1 to calculate the assist target torque Tat.

Further, the assist torque calculation task 53 includes a divider 60 that divides an output of the Min calculator 58 by the output of the engine setting torque table 57 and calculates an engine load ratio Rel, a lower limit limiter 61 that extracts a plus component of the assist target torque Tat

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output from the subtracter 59, an upper limit limiter 62 that extracts a minus component, an assist correction coefficient setter 63 functioning as a correction coefficient setter that outputs an assist correction coefficient according to the engine load ratio Rel calculated by the divider 60, a charge correction coefficient setter 64 functioning as a correction coefficient setter that outputs a charge correction coefficient, a multiplier 65 that multiplies the plus component of the assist target torque Tat output from the lower limit limiter 61 with an output of the assist correction coefficient setter 63, a multiplier 66 that multiplies the minus component of the assist target torque Tat output from the upper limit limiter 62 with an output of the charge correction coefficient setter 64, and an adder 67 that adds up outputs of the multiplier 65 and the multiplier 66.

The assist torque calculation task 53 includes a NOT operation unit 68 that reverses a signal of the operation pilot pressure Ppi and outputs a signal of OFF in machine operation and outputs a signal of ON in non-operation and an OR operation unit 69 that calculates an OR of an output of the NOT operation unit 68 and the boom lowering pilot pressure Pbd. An OR operation by the OR operation unit 69 is summarized in Table 1 below.

TABLE 1

Output of NOT operation unit 68 or 79	Machine operation state OFF	Machine operation state OFF	Machine non-operation state ON	Machine non-operation state ON
Output of boom lowering pilot pressure Pbd	Boom lowering operation ON	Boom lowering non-operation OFF	Boom lowering operation ON	Boom lowering non-operation OFF
Output of OR operation unit 69 or 80	ON	OFF	ON	ON

Further, the assist torque calculation task 53 includes a switch 70 that switches according to an output of the OR operation unit 69. The switch 70 selects an output of the adder 67 when the output of the OR operation unit 69 is OFF and selects an output "0" of a zero setter 71 when the output of the OR operation unit 69 is ON.

FIG. 9 shows calculation blocks of the engine torque feedback control task 54. The accumulator pressure Pac, the main pump load torque D1, the accelerator dial 32, the operation pilot pressure Ppi, the boom lowering pilot pressure Pbd, and the engine actual torque Tea are input to the engine torque feedback control task 54. Assist correction torque D3 is output as an output of a control operation.

The engine torque feedback control task 54 includes a low-pass filter 72 same as the low-pass filter 56 that separates and extracts the smooth torque component Tsm from the main pump load torque D1, an engine setting torque table 73 same as the engine setting torque table 57, a correction torque table 74 that outputs correction torque on the basis of the accumulator pressure Pac, an adder 75 that adds up the smooth torque component Tsm treated by the low-pass filter 72 and an output of the correction torque table 74, a Min calculator 76 that compares an output (the engine setting torque Tes) of the engine setting torque table 73 and an output of the adder 75 and selects a smaller value, a subtracter 77 that calculates a deviation signal ΔT obtained by feeding back the engine actual torque Tea to the engine target torque Tet output from the Min calculator 76, and a

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control operation unit 78 that subjects the deviation signal ΔT output from the subtracter 77 to PID operation processing.

Further, the engine torque feedback control task 54 includes a NOT operation unit 79 and an OR operation unit 80 that reverse a signal of the operation pilot pressure Ppi. The NOT operation unit 79 outputs a signal of OFF in machine operation and outputs a signal of ON in non-operation. The OR operation unit 80 calculates an OR of an output of the NOT operation unit 79 and the boom lowering pilot pressure Pbd. An output of the OR operation unit 80 is the same as the above Table 1. The control operation unit 78 is reset when the output of the OR operation unit 80 is ON. An output of the control operation unit 78 is output as the assist correction torque D3.

(4) Assist Pump Swash Plate Control Task S4

FIG. 10 shows calculation blocks of the assist pump swash plate control task S4. The assist pump inlet pressure Pin, the assist pump outlet pressure Pout, the accumulator pressure Pac, and the assist request torque D4 are input to the assist pump swash plate control task S4. The assist pump swash plate command D5 is output from the assist pump swash plate control task S4.

The assist pump swash plate control task S4 includes a subtracter 81 functioning as assist pump differential pressure acquiring means for calculating an assist pump differential pressure ΔP between the assist pump inlet pressure Pin and the assist pump outlet pressure Pout, a lower limit limiter 82 that extracts a plus component of the assist request torque D4, an assist upper limit torque setter 83 that sets assist upper limit torque on the basis of the accumulator pressure Pac, a Min calculator 84 that compares an output of the lower limit limiter 82 and an output of the assist upper limit torque setter 83 and selects a smaller value, an upper limit limiter 85 that extracts a minus component of the assist request torque D4, a charge upper limit torque setter 86 that sets charge upper limit torque on the basis of the accumulator pressure Pac, and a maximum selection calculator (hereinafter referred to as Max calculator) 87 that compares an output of the upper limit limiter 85 and an output of the charge upper limit torque setter 86 and selects a larger value.

Further, the assist pump swash plate control task S4 includes an assist swash plate angle calculator 88 that calculates an assist swash plate angle φ_{as} in an engine assist mode of the assist pump 10 on the basis of an output T of the Min calculator 84 and the assist pump differential pressure ΔP output from the subtracter 81 and a charge swash plate angle calculator 89 that calculates a charge swash plate angle φ_{as} in an accumulator charge mode of the assist pump 10 on the basis of an output T of the Max calculator 87 and the assist pump differential pressure ΔP output from the subtracter 81.

The assist swash plate angle calculator 88 calculates the assist pump swash plate angle φ (the assist swash plate angle φ_{as}) according to the following expression and outputs the assist pump swash plate angle φ.

$$Das=(2\pi\cdot Tas)/(\Delta P\cdot\eta_{mt})$$

$$\phi_{as}=\text{Min}(0, Das/Dpm)$$

Dpm: Assist pump maximum capacity

η_{mt}: Torque efficiency

The charge swash plate angle calculator 89 calculates the assist pump swash plate angle φ (the charge swash plate angle φ_{ch}) according to the following expression and outputs the assist pump swash plate angle φ.

$$Dch=(2\pi\cdot\eta_{pt}\cdot Tch)/\Delta P$$

$$\phi_{ch}=\text{Min}(0, Dch/Dpm)$$

Dpm: Assist pump maximum capacity
 η_{pt} : Torque efficiency

The assist pump swash plate control task S4 includes a switch 90 that switches an output (the assist swash plate angle ϕ_{as}) of the assist swash plate angle calculator 88 and an output (the charge swash plate angle ϕ_{ch}) of the charge swash plate angle calculator 89 according to plus/minus of the assist request torque D4. The assist pump swash plate angle ϕ (the assist swash plate angle ϕ_{as} or the charge swash plate angle ϕ_{ch}) serving as the assist pump swash plate command D5 is output from the switch 90 to the swash plate angle adjusting unit 10 ϕ of the assist pump 10.

(5) Valve Control Task S5

FIG. 11 shows calculation blocks of the valve control task S5. The assist request torque D4 output from the assist pump swash plate control task S4 and the boom lowering pilot pressure Pbd are input to the valve control task S5. Switching signals for the unload valve 12 and the accumulator regeneration valve 13 are output on the basis of a control operation result.

The valve control task S5 includes a switch 91 that switches according to the assist request torque D4, an OPEN output unit 92, and a CLOSE output unit 93. The switch 91 selects a signal of the OPEN output unit 92 in the case of the assist request torque $D4 \geq 0$ and selects a signal of the CLOSE output unit 93 in the case of the assist request torque $D4 < 0$.

Further, the valve control task S5 includes a switch 94 that switches according to the boom lowering pilot pressure Pbd and an OPEN output unit 95. The switch 94 selects a signal of the OPEN output unit 95 in the case of the boom lowering pilot pressure Pbd=ON, selects a signal of the switch 91 in the case of the boom lowering pilot pressure Pbd=OFF, and outputs the signal as a command for the unload valve 12.

Further, the valve control task S5 includes a switch 96 that switches according to the assist request torque D4, an OPEN output unit 97, and a CLOSE output unit 98. The switch 96 outputs a signal of the OPEN output unit 97 in the case of the assist request torque $D4 > 0$ and outputs a signal of the CLOSE output unit 98 in the case of the assist request torque $D4 \leq 0$.

Further, the valve control task S5 includes a switch 99 that switches according to the boom lowering pilot pressure Pbd and a CLOSE output unit 100. The switch 99 selects a signal of the CLOSE output unit 100 in the case of the boom lowering pilot pressure Pbd=ON, selects a signal of the switch 96 in the case of the boom lowering pilot pressure Pbd=OFF, and outputs the signal as a command for the accumulator regeneration valve 13.

The action explained above is summarized in Table 2.

TABLE 2

State of assist pump 10	Boom lowering pilot pressure Pbd	Assist request torque D4	Unload valve 12	Accumulator regeneration valve 13
Swash plate: Min No load	Boom lowering operation ON	+	Open	Close
Assist Swash plate: Min No load	Boom lowering operation OFF	0	Open	Close
Charge		-	Close	Close

A control algorithm and action and effects of the control algorithm are explained on the basis of FIG. 4 to FIG. 16.

First, a rough flow of control is explained on the basis of a control block diagram of FIG. 5.

The main pump load torque D1 is calculated by the main pump load torque calculation task S2 on the basis of the main pump pressures Pf and Pr and the main pump swash plate angles θ_f and θ_r .

The main pump load torque D1 is input to the assist request torque calculation task S3. Assist torque D2 is calculated by the assist torque calculation task 53. The assist correction torque D3 is calculated by the engine torque feedback control task 54. The assist torque D2 and the assist correction torque D3 are added up by the adder 55 and output as the assist request torque D4.

The assist request torque D4 is input to the assist pump swash plate control task S4. The assist pump swash plate angle ϕ serving as the assist pump swash plate command D5 is calculated. The swash plate angle adjusting unit 10 ϕ of the assist pump 10 is controlled. The assist request torque D4 is input to the valve control task S5. The switching signals for the unload valve 12 and the accumulator regeneration valve 13 are output. The unload valve 12 and the accumulator regeneration valve 13 are controlled.

A calculation process of the control is explained below.

(a) Assist Torque Calculation Task 53 (See FIG. 8)

The main pump load torque D1 is subjected to filter processing by the low-pass filter 56 and the smooth torque component Tsm is extracted. The engine setting torque Tes is output by the engine setting torque table 57 on the basis of a signal (the accelerator dial value Ad) input from the accelerator dial 32. The smooth torque component Tsm output from the low-pass filter 56 and the engine setting torque Tes output from the engine setting torque table 57 are compared and a smaller value is selected as the engine target torque Tet by the Min calculator 58.

Further, a difference between the main pump load torque D1 and the engine target torque Tet output from the Min calculator 58 is calculated by the subtracter 59. A fluctuation component of the main pump load torque D1 is extracted as the assist target torque Tat.

A result of the calculation explained above is shown in a characteristic chart of engine assist control in FIG. 12. An output of the Min calculator 58 is equivalent to the engine target torque Tet and an output of the subtracter 59 is equivalent to the assist target torque Tat.

A plus component of the assist target torque Tat in FIG. 12 is torque for the assist pump 10 to perform motor action to assist driving torque of the engine 6. A minus component of the assist target torque Tat is a torque for driving the assist pump 10 with the engine 6 to perform pump action and charge the accumulator 11.

Referring back to FIG. 8, the output (the engine target torque Tet) of the Min calculator 58 is divided by an output of the engine setting torque table 57 and the engine load ratio Rel is calculated by the divider 60. A plus component (assist torque by the motor action) of the output (the assist target torque Tat) of the subtracter 59 is extracted by the lower limit limiter 61. A minus component (charge torque by the pump action) is extracted by the upper limit limiter 62.

An assist correction coefficient is calculated by the assist correction coefficient setter 63 on the basis of the engine load ratio Rel calculated by the divider 60. Similarly, a charge correction coefficient is calculated by the charge correction coefficient setter 64.

As shown in FIG. 13, the assist correction coefficient setter 63 is set to increase the assist correction coefficient when the engine load ratio Rel is high and reduce the assist correction coefficient when the engine load ratio Rel is low.

As shown in FIG. 14, the charge correction coefficient setter **64** is set to a characteristic opposite to the characteristic of the assist correction coefficient setter **63**.

The plus component of the assist target torque T_{at} output from the lower limit limiter **61** is multiplied with an output of the assist correction coefficient setter **63** by the multiplier **65**. Similarly, the minus component of the assist target torque T_{at} output from the upper limit limiter **62** is multiplied with an output of the charge correction coefficient setter **64** by the multiplier **66**. Outputs of the multiplier **65** and the multiplier **66** are added up by the adder **67**.

The switch **70** selects an output of the adder **67** when an output of the OR operation unit **69** is OFF and selects an output "0" of the zero setter **71** when the output of the OR operation unit **69** is ON. The output of the OR operation unit **69** is set as shown in the above Table 1. Therefore, the output is OFF in a machine operation state other than boom lowering and the output of the adder **67** is selected. In boom lowering operation or a non-operation state of a machine, ON is output from the OR operation unit **69** and the output "0" of the zero setter **71** is selected.

When the assist torque $D2$ is (+), a mode of the assist pump **10** is the engine assist mode by the motor action. When the assist torque $D2$ is (-), the mode of the assist pump **10** is the accumulator charge mode by the pump action.

(b) Engine Torque Feedback Control Task **54** (See FIG. 9).

The smooth torque component T_{sm} is extracted from the main pump load torque $D1$ by the low-pass filter **72**. The engine setting torque T_{es} is output by the engine setting torque table **73**. Correction torque is output by the correction torque table **74** on the basis of the accumulator pressure P_{ac} . As shown in FIG. 15, the correction torque table **74** is set to increase the correction torque when the accumulator pressure P_{ac} decreases.

The smooth torque component T_{sm} processed by the low-pass filter **72** and the output of the correction torque table **74** are added up by the adder **75**. The output of the engine setting torque table **73** and an output of the adder **75** are compared and smaller value is selected and output as the engine target torque T_{et} by the Min calculator **76**.

The deviation signal ΔT between the engine target torque T_{et} output from the Min calculator **76** and the engine actual torque T_{ea} detected by the engine torque sensor **41** is calculated by the subtracter **77**. The deviation signal ΔT is subjected to PID operation processing by the control operation unit **78** and the assist correction torque $D3$ is output. When the assist correction torque $D3$ is (+), the mode of the assist pump **10** is the engine assist mode by the motor action. When the assist correction torque $D3$ is (-), the mode of the assist pump **10** is the accumulator charge mode by the pump action.

The control operation unit **78** is reset when an output of the OR operation unit **80** is ON. Like the OR operation unit **69** shown in FIG. 8, the output of the OR operation unit **80** is set as shown in the above Table 1. Therefore, in a machine operation state other than boom lowering, the output of the OR operation unit **80** is OFF. The control operation unit **78** outputs the assist correction torque $D3$. In the boom lowering operation or in the non-operation state of the machine, ON (a reset signal) is output from the OR operation unit **80**. The output of the control operation unit **78** decreases to zero.

When the assist correction torque $D3$ is (+), the mode of the assist pump **10** is the engine assist mode by the motor

action. When the assist correction torque $D3$ is (-), the mode of the assist pump **10** is the accumulator charge mode by the pump action.

The assist correction torque $D3$ calculated as explained above is added to the assist torque $D2$ as shown in FIG. 7 to be the assist request torque $D4$. When the assist request torque $D4$ is (+), the mode of the assist pump **10** is the engine assist mode by the motor action. When the assist request torque $D4$ is (-), the mode of the assist pump **10** is the accumulator charge mode by the pump action.

(c) Assist Pump Swash Plate Control Task **S4** (See FIG. 10)

The assist request torque $D4$ output from the assist request torque calculation task **S3** is input to the assist pump swash plate control task **S4**. The assist pump swash plate angle ϕ serving as the assist pump swash plate command $D5$ is calculated by calculation explained below.

The assist pump differential pressure ΔP between the assist pump inlet pressure P_{in} and the assist pump outlet pressure P_{out} is calculated by the subtracter **81**. A plus component of the assist request torque $D4$ is extracted by the lower limit limiter **82**. An assist upper limit torque is set by the assist upper limit torque setter **83** on the basis of the accumulator pressure P_{ac} . An output of the lower limit limiter **82** and an output of the assist upper limit torque setter **83** are compared and a smaller value is selected by the Min calculator **84**.

Similarly, a minus component of the assist request torque $D4$ is extracted by the upper limit limiter **85**. A charger upper limit torque is set by the charge upper limit torque setter **86** on the basis of the accumulator pressure P_{ac} . An output of the upper limit limiter **85** and an output of the charge upper limit torque setter **86** are compared and a larger value is selected by the Max calculator **87**.

An assist pump swash plate angle command value (the assist swash plate angle ϕ_{as}) during assist is calculated by the assist swash plate angle calculator **88** on the basis of an output of the Min calculator **84** and the assist pump differential pressure ΔP output from the subtracter **81**. Similarly, an assist pump swash plate angle command value (the charge swash plate angle ϕ_{ch}) during charging is calculated by the charge swash plate angle calculator **89** on the basis of an output of the Max calculator **87** and the assist pump differential pressure ΔP output from the subtracter **81**.

An output of the assist swash plate angle calculator **88** and an output of the charge swash plate angle calculator **89** are switched by the switch **90** according to plus/minus of the assist request torque $D4$. The assist pump swash plate angle ϕ (the assist swash plate angle ϕ_{as} or the charge swash plate angle ϕ_{ch}) serving as the assist pump swash plate command $D5$ is output and the swash plate of the assist pump **10** is controlled.

(d) Valve Control Task **S5** (See FIG. 11)

The unload valve **12** and the accumulator regeneration valve **13** are controlled as shown in Table 2 by logical operation blocks of the valve control task **S5** shown in FIG. 11.

(e) Summary

According to the action explained above, as shown in FIG. 8, smooth torque is extracted from the main pump load torque $D1$ by the low-pass filter **56**. A difference between the main pump load torque $D1$ and the smooth torque is set as the assist torque $D2$. The assist torque $D2$ is corrected according to a load state of the engine and adjusted to increase assist torque when the engine load ratio Rel is high and increase charge torque when the engine load ratio Rel is low.

As shown in FIG. 9, the smooth torque is set as the engine target torque T_{et} , the engine actual torque T_{ea} is fed back to calculate the deviation signal ΔT between the engine target torque T_{et} and the engine actual torque T_{ea} . The assist correction torque $D3$ is calculated by PID control (proportional, integral, and differential control) or the like.

The assist torque $D2$ is a feed-forward component and the assist correction torque $D3$ is a feedback component. As shown in FIG. 7, the assist torque $D2$ and the assist correction torque $D3$ are added up as the assist request torque $D4$. The swash plate of the assist pump **10** is controlled to assist the engine **6**.

In boom lowering operation, the unload valve **12** is opened and the accumulator regeneration valve **13** is closed to minimize the angle of the swash plate of the assist pump **10**. Therefore, pressure oil in the head chamber of the boom cylinder **3a** during boom lowering is directly charged in the accumulator **11**.

Effects of the embodiment shown in FIG. 1 to FIG. 16 are enumerated below.

As shown in FIG. 12, the main pump load torque $D1$ is separated into the assist target torque T_{at} and the engine target torque T_{et} . The torque of the assist pump **10** is controlled to be the assist target torque T_{at} and assists the engine. Therefore, it is possible to smoothly change the engine actual torque T_{ea} like the engine target torque T_{et} .

When the pressure of the accumulator **11** decreases, control is performed to gradually increase the engine target torque T_{et} and perform charging. Then, the engine target torque T_{et} smoothed by the engine setting torque T_{es} becomes more flat. Therefore, it is possible to effectively suppress load fluctuation of the engine. This leads to suppression of exhaust gas, a reduction in the size of the engine **6**, and a reduction in the size of a post processing device, that is, an exhaust gas purifier involved in the suppression of the exhaust gas and the reduction in the size of the engine **6**.

Since the engine **6** is assisted using the pressure oil of the accumulator **11**, as shown in FIG. 16, the engine setting torque T_{es} set by the accelerator dial **32** can be set lower than the main pump load torque $D1$. Therefore, it is possible to operate the engine in a region with high fuel efficiency and further improve the fuel efficiency.

Pressure oil of the boom lowering and the swing brake is accumulated in the accumulator **11** and, when the load of the engine **6** is low, pressure is accumulated in the accumulator **11** by the assist pump **10**. Therefore, it is possible to sufficiently secure energy for assisting the engine **6**. Therefore, it is possible to reduce the engine **6** in size and reduce a cooling device for the engine and a related device such as an air cleaner in size according to the reduction in the size of the engine.

The engine **6** is assisted by the assist pump **10** during high load of the engine **6** and pressure is accumulated in the accumulator **11** by the assist pump **10** during low load of the engine **6**. Therefore, it is possible to smooth the load of the engine **6** and the fuel efficiency is improved. Further, it is possible to reduce exhaust gas such as black smoke.

Since the pressure oil of the boom lowering and the swing brake is collected, it is possible to reduce an energy loss of a hydraulic device and reduce a hydraulic cooling device in size.

Since the system is configured by the hydraulic machine, compared with the hybrid system in which the electric system is used, it is possible to substantially reduce costs, maintenance is less frequently performed, and it is possible to reduce running costs. Further, it is possible to easily mount the system on the conventional working machine.

The smooth torque component T_{sm} is separated from the main pump load torque $D1$ by the subtracter **59** functioning as the assist target torque calculating means. The minimum of the smooth torque component T_{sm} and the engine setting torque T_{es} is set as the engine target torque T_{et} . The engine actual torque T_{ea} is controlled by the engine controller **31** according to the engine target torque T_{et} . The assist target torque T_{at} is calculated by the subtracter **59** from a difference between the main pump load torque $D1$ and the engine target torque T_{et} . The capacity (i.e., the assist pump swash plate angle ϕ) of the assist pump **10** and the switching of the assist mode of the engine **6** and the charge mode of the accumulator **11** (the switching of the unload valve **12** and the accumulator regeneration valve **13**) are controlled by the machine controller **30** on the basis of the assist target torque T_{at} . Therefore, load fluctuation is absorbed by the control of the assist pump capacity and the mode switching by the machine controller **30** having high responsiveness to a torque request that frequently changes. Consequently, it is possible to smooth the engine target torque T_{et} and smoothly change the engine actual torque T_{ea} according to the engine target torque T_{et} . Moreover, a large-capacity generator motor, battery, or the like is unnecessary. Therefore, it is possible to provide the small and inexpensive control device **C** that can effectively suppress load fluctuation of the engine **6** according to, for example, a state of the main pump circuit.

In particular, the engine target torque calculation task **101** sets, as the engine target torque T_{et} , the minimum of the smooth torque component T_{sm} separated from the main pump load torque $D1$ and the engine setting torque T_{es} . Therefore, when the pressure of the accumulator **11** decreases, the control is performed to gradually increase the engine target torque T_{et} and perform charging. Therefore, it is possible to more flatly change the engine target torque T_{et} smoothed by the engine setting torque T_{es} . It is possible to effectively suppress load fluctuation of the engine **6**. Further it is possible to attain suppression of exhaust gas and a reduction in the size of the engine **6** and the post processing device of the engine **6**, that is, the exhaust gas purifier.

The assist target torque T_{at} is multiplied with the engine load ratio Rel , which is calculated by dividing the engine target torque T_{et} by the engine setting torque T_{es} , to calculate the assist torque $D2$ as the feed-forward torque. Further, the assist correction torque $D3$ is calculated on the basis of the deviation signal ΔT obtained by feeding back the engine actual torque T_{ea} to the engine target torque T_{et} . The assist torque $D2$ and the assist correction torque $D3$ are added up to calculate the assist request torque $D4$. Therefore, according to the accurate assist request torque $D4$ corrected by the engine load ratio Rel and the engine actual torque T_{ea} , it is possible to output the accurate assist pump swash plate command $D5$ to the assist pump **10** that variably adjusts the pump capacity according to the assist pump swash plate angle ϕ .

The engine target torque T_{et} is divided by the engine setting torque T_{es} to calculate the engine load ratio Rel . The assist target torque T_{at} is corrected to increase the assist torque when the engine load ratio Rel is high and increase the charge torque when the engine load ratio Rel is low. Therefore, it is possible to appropriately adjust the assist target torque T_{at} according to a load state of the engine **6**.

When the machine body **B** and the front working device **F** are actuated in the working machine hydraulically driven **HE**, with the accumulator **11** of the control device **C** including the function of accumulating and discharging brake energy of the swing motor **9** of the machine body **B** and position energy of the boom cylinder **3a** and the like of

the front working device F, it is possible to effectively use the brake energy and the position energy of the working machine HE. It is possible to effectively suppress load fluctuation of the engine 6. It is possible to attain suppression of exhaust gas and a reduction in the sizes of the engine 6 and the post processing device.

FIG. 17 is an assist command torque calculation task S3a showing another embodiment of the assist request torque calculation task S3 that calculates the assist request torque D4, which is a torque command value of the assist pump 10, in the machine controller 30. Note that the components shown in FIG. 1 to FIG. 4, FIG. 6, FIG. 10, and FIG. 11 are the same. Therefore, explanation of the components is omitted.

The assist command torque calculation task S3a includes the engine target torque calculation task 101 functioning as engine target torque calculating means for calculating the engine target torque Tet from the main pump load torque D1 and the accelerator dial value Ad, a subtracter 102 that calculates the deviation signal ΔT between the engine target torque Tet and the engine actual torque Tea, and a control operation unit 103 that subjects the deviation signal ΔT output from the subtracter 102 to PID control.

As shown in FIG. 8, the engine target torque calculation task 101 separates, with the low-pass filter 56, the smooth torque component Tsm from the main pump load torque D1 and outputs, as the engine target torque Tet, a minimum selected by comparing, with the Min calculator 58, the smooth torque component Tsm and the engine setting torque Tes calculated by the engine setting torque table 57 from the accelerator dial value Ad.

Therefore, the smooth torque component Tsm is separated from the main pump load torque D1 and the minimum of the smooth torque component Tsm and the engine setting torque Tes is set as the engine target torque Tet by the engine target torque calculation task 101. The deviation signal ΔT between the engine target torque Tet and the engine actual torque Tea obtained from the engine controller 31 is subjected to the PID control to calculate a torque command value (the assist request torque D4) of the assist pump 10. The capacity (i.e., the assist pump swash plate angle ϕ) of the assist pump 10 and the switching of the assist mode of the engine 6 and the charge mode of the accumulator 11 are controlled by the assist pump swash plate control task S4 and the valve control task S5 shown in FIG. 5 on the basis of the torque command value.

In this way, load fluctuation is absorbed by the assist pump capacity control and the mode switching control by the machine controller 30 having high responsiveness to a torque request that frequently changes. Consequently, it is possible to smooth the engine target torque Tet and smoothly change the engine actual torque Tea according to the engine target torque Tet. Moreover, a large-capacity generator motor, battery, or the like is unnecessary. Therefore, it is possible to provide the small and inexpensive control device C that can effectively suppress load fluctuation of the engine 6 according to, for example, a state of the main pump circuit.

Further, as indicated by a portion surrounded by an alternate long and two short dashes line in FIG. 17, the assist command torque calculation task S3a includes an adder 104 that detects a sum of the main pump pressures Pf and Pr detected by the pump pressure sensors 33 and 34, a main pump pressure determination table 105 functioning as main pump pressure determining means for outputting an ON signal when the sum of the main pump pressures Pf and Pr is higher than first specified pressure Pon and outputting an OFF signal when the sum of the main pump pressures Pf and

Pr is lower than second specified pressure Poff (smaller than the first specified pressure Pon), and a switch 106 that switches according to an output of the main pump pressure determination table 105.

The switch 106 selects an output of the control operation unit 103 when an output of the main pump pressure determination table 105 is OFF and selects a torque "0" of a zero setter 107 when the output of the main pump pressure determination table 105 is ON.

The engine target torque Tet is calculated and set from the main pump load torque D1 or the like by the engine target torque calculation task 101. The engine actual torque Tea output from the engine controller 31 is fed back to the engine target torque Tet. The deviation signal ΔT between the engine target torque Tet and the engine actual torque Tea is calculated by the subtracter 102. The deviation signal ΔT is subjected to the PID control by the control operation unit 103.

As indicated by the portion surrounded by the alternate long and two short dashes line in FIG. 17, when the sum of the main pump pressures Pf and Pr is higher than the first specified pressure Pon, the switch 106 switches from the OFF side to the ON side according to the ON signal output from the main pump pressure determination table 105. Therefore, a torque command value (the assist request torque D4) of the assist pump 10 changes to "0". The assist of the engine 6 by the assist pump 10 and the pressure accumulation of the accumulator 11 are stopped.

When the sum of the main pump pressures Pf and Pr is lower than the second specified pressure Poff, the switch 106 switches from the ON side to the OFF side according to the OFF signal output from the main pump pressure determination table 105. The assist of the engine 6 by the assist pump 10 and the pressure accumulation of the accumulator 11 are resumed. An output subjected to the PID control by the control operation unit 103 becomes the torque command value (the assist request torque D4) of the assist pump 10. When the assist request torque D4 is "+", the torque of the assist pump 10 is engine assist torque for assisting the engine 6 with the assist pump 10. When the assist request torque D4 is "-", the torque of the assist pump 10 is accumulator charge torque for accumulating pressure in the accumulator 11 with the assist pump 10.

Therefore, in a relief state in which a relief valve (not shown in the figure) provided in a discharge circuit of the main pumps 7 and 8 performs relief operation, that is, in a relief state in which the sum of the main pump pressures Pf and Pr is higher than the specified pressure Pon, the torque command value of the assist pump 10 is set to zero to stop the assist of the engine 6. When the sum of the main pump pressures Pf and Pr is lower than the specified pressure Poff, the assist of the engine 6 is resumed. That is, the engine 6 is not assisted during the relief state. Therefore, it is possible to prevent useless consumption of energy accumulated in the accumulator 11.

By providing a dead zone between the specified pressures Pon and Poff according to hysteresis of the main pump pressure determination table 105, it is possible to prevent unstable ON/OFF switching and secure stability of a control system.

Note that, when the assist command torque calculation task S3a does not include the portion surrounded by the alternate long and two short dashes line in FIG. 17, even when the main pump pressures Pf and Pr of the hydraulic oil discharged from the main pumps 7 and 8 rise and the assist command torque calculation task S3a changes to the relief state, the pressure oil of the accumulator 11 is supplied to the

assist pump **10** to assist the engine **6**. Therefore, the energy of the accumulator **11** is uselessly consumed.

INDUSTRIAL APPLICABILITY

The present invention has industrial applicability for business operators that, for example, manufacture and sell a control device including an assist pump and an accumulator and a working machine mounted with the control device.

EXPLANATION OF REFERENCE NUMERALS

HE Working machine
 B Machine body
 F Front working device functioning as working device
 C Control device
 6 Engine
 7 Front pump functioning as main pump
 8 Rear pump functioning as main pump
 10 Assist pump
 10 ϕ Swash plate angle adjusting unit
 11 Accumulator
 30 Machine controller functioning as assist pump control means
 31 Engine controller functioning as engine control means
 32 Accelerator dial functioning as accelerator means
 33, 34 Pump pressure sensors
 37 Accumulator pressure sensor functioning as accumulator pressure detecting means
 41 Engine torque sensor functioning as engine actual torque acquiring means
 53 Assist torque calculation task functioning as assist torque calculating means
 54 Engine torque feedback control task functioning as engine torque feedback control means
 55 Adder
 59 Subtractor functioning as assist target torque calculating means
 60 Divider
 63 Assist correction coefficient setter functioning as correction coefficient setter
 64 Charge correction coefficient setter functioning as correction coefficient setter
 65, 66 Multipliers
 81 Subtractor functioning as assist pump differential pressure acquiring means
 101 Engine target torque calculation task functioning as engine target torque calculating means
 102 Subtractor
 103 Control operation unit
 106 Switch
 Pac Accumulator pressure
 Pin Assist pump inlet pressure
 Pout Assist pump outlet pressure
 ΔP Assist pump differential pressure
 ϕ Assist pump swash plate angle
 Tsm Smooth torque component
 Tes Engine setting torque
 Tet Engine target torque
 Tat Assist target torque
 Rel Engine load ratio
 Tea Engine actual torque
 ΔT Deviation signal
 D1 Main pump load torque
 D2 Assist torque serving as feed-forward torque
 D3 Assist correction torque

D4 Assist request torque
 D5 Assist pump swash plate command
 S2 Main pump load torque calculation task functioning as main pump load torque calculating means
 5 S4 Assist pump swash plate control task functioning as assist pump swash plate control means
 Pf Front pump pressure serving as main pump pressure
 Pr Rear pump pressure serving as main pump pressure
 Pon Specified pressure
 10 Poff Specified pressure
 FIG. 1
 C CONTROL DEVICE
 6 ENGINE
 31 ENGINE CONTROL MEANS
 15 11 ACCUMULATOR
 37 ACCUMULATOR PRESSURE DETECTING MEANS
 30 ASSIST PUMP CONTROL MEANS
 7, 8 MAIN PUMP
 10 ASSIST PUMP
 20 10 ϕ SWASH PLATE ANGLE ADJUSTING UNIT
 32 ACCELERATOR MEANS
 33, 34 PUMP PRESSURE SENSOR
 41 ENGINE ACTUAL TORQUE ACQUIRING MEANS
 FIG. 2
 25 HE WORKING MACHINE
 F WORKING DEVICE
 B MACHINE BODY
 FIG. 3
 32 ACCELERATOR DIAL VALUE Ad
 30 33 FRONT PUMP PRESSURE Pf
 34 REAR PUMP PRESSURE PR
 35 35 FRONT PUMP SWASH PLATE ANGLE θ_f
 36 REAR PUMP SWASH PLATE ANGLE θ_r
 37 ACCUMULATOR PRESSURE Pac
 38 ASSIST PUMP INLET PRESSURE Pin
 39 ASSIST PUMP OUTLET PRESSURE Pout
 42 OPERATION PILOT PRESSURE Ppi
 43 BOOM LOWERING PILOT PRESSURE Pbd
 30 MACHINE CONTROLLER
 40 17 ELECTROMAGNETIC PROPORTIONAL VALVE FOR POWER SHIFT
 10 ϕ ASSIST PUMP SWASH PLATE
 12 UNLOAD VALVE
 13 ACCUMULATOR REGENERATION VALVE
 45 D6 ENGINE SETTING SPEED
 ENGINE ACTUAL SPEED Ne
 ENGINE ACTUAL TORQUE Tea
 31 ENGINE CONTROLLER
 6 ENGINE
 50 40 ENGINE ACTUAL SPEED Ne
 41 ENGINE ACTUAL TORQUE Tea
 FIG. 4
 START
 S1 INPUT PROCESSING TASK
 55 S2 MAIN PUMP LOAD TORQUE CALCULATION TASK
 MAIN PUMP LOAD TORQUE CALCULATING MEANS
 S3 ASSIST REQUEST TORQUE CALCULATION TASK
 S4 ASSIST PUMP SWASH PLATE CONTROL TASK
 60 ASSIST PUMP SWASH PLATE CONTROL MEANS
 S5 VALVE CONTROL TASK
 RETURN TO START
 FIG. 5
 30 ASSIST PUMP CONTROL MEANS
 65 41 ENGINE ACTUAL TORQUE Tea
 32 ACCELERATOR DIAL VALUE Ad
 37 ACCUMULATOR PRESSURE Pac

42 OPERATION PILOT PRESSURE P_{pi}
43 BOOM LOWERING PILOT PRESSURE P_{bd}
33, 34 MAIN PUMP PRESSURES P_f, P_r
35, 36 MAIN PUMP SWASH PLATE ANGLES θ_f, θ_r
38 ASSIST PUMP INLET PRESSURE P_{in}
39 ASSIST PUMP OUTLET PRESSURE P_{out}
S2 MAIN PUMP LOAD TORQUE CALCULATION TASK
54 ENGINE TORQUE FEEDBACK CONTROL TASK
53 ASSIST TORQUE CALCULATION TASK
S5 VALVE CONTROL TASK
S4 ASSIST PUMP SWASH PLATE CONTROL TASK
53 ASSIST TORQUE CALCULATING MEANS
54 ENGINE TORQUE FEEDBACK CONTROL MEANS
55 ADDER
D1 MAIN PUMP LOAD TORQUE
D2 ASSIST TORQUE
D3 ASSIST CORRECTION TORQUE
D4 ASSIST REQUEST TORQUE
13 ACC REGENERATION VALVE COMMAND
12 UNLOAD VALVE COMMAND
D5 ASSIST PUMP SWASH PLATE COMMAND
10 ϕ ASSIST PUMP SWASH PLATE ANGLE ϕ
 FIG. 6
33 FRONT PUMP PRESSURE P_f
35 FRONT PUMP SWASH PLATE ANGLE θ_f
34 REAR PUMP PRESSURE P_r
36 REAR PUMP SWASH PLATE ANGLE θ_r
 PUMP TORQUE CALCULATION
 PUMP MAXIMUM CAPACITY
 TORQUE EFFICIENCY
D1 MAIN PUMP LOAD TORQUE
 FIG. 7
37 ACCUMULATOR PRESSURE P_{ac}
D1 MAIN PUMP LOAD TORQUE
32 ACCELERATOR DIAL VALUE A_d
42 OPERATION PILOT PRESSURE P_{pi}
43 BOOM LOWERING PILOT PRESSURE P_{bd}
41 ENGINE ACTUAL TORQUE T_{ea}
54 ENGINE TORQUE FEEDBACK CONTROL TASK
53 ASSIST TORQUE CALCULATION TASK
55 ADDER
D4 ASSIST REQUEST TORQUE
 REQUEST TORQUE
 ASSIST
 CHARGE
 FIG. 8
53 ASSIST TORQUE CALCULATING MEANS
42 OPERATION PILOT PRESSURE P_{pi}
43 BOOM LOWERING PILOT PRESSURE P_{bd}
D1 MAIN PUMP LOAD TORQUE
32 ACCELERATOR DIAL VALUE A_d
59 ASSIST TARGET TORQUE CALCULATING MEANS
56 LPF PROCESSING
 ENGINE SETTING TORQUE
 ACCELERATOR DIAL
101 ENGINE TARGET TORQUE CALCULATING
 MEANS
56 LOW-PASS FILTER
60 DIVIDER
63, 64 CORRECTION COEFFICIENT SETTER
65, 66 MULTIPLIER
 T_{sm} SMOOTH TORQUE COMPONENT
 T_{es} ENGINE SETTING TORQUE
 T_{et} ENGINE TARGET TORQUE
 T_{at} ASSIST TARGET TORQUE
 Rel ENGINE LOAD RATIO.

D2 ASSIST TORQUE
 ASSIST TORQUE
 ASSIST
 CHARGE
 FIG. 9
54 ENGINE TORQUE FEEDBACK CONTROL MEANS
37 ACCUMULATOR PRESSURE P_{ac}
D1 MAIN PUMP LOAD TORQUE
32 ACCELERATOR DIAL VALUE A_d
41 ENGINE ACTUAL TORQUE T_{ea}
42 OPERATION PILOT PRESSURE P_{pi}
43 BOOM LOWERING PILOT PRESSURE P_{bd}
 CORRECTION TORQUE
 ACC PRESSURE
72 LPF PROCESSING
15 ENGINE SETTING TORQUE
 ACCELERATOR DIAL
D3 ASSIST CORRECTION TORQUE
 ASSIST TORQUE
 ASSIST
20 CHARGE
 T_{sm} SMOOTH TORQUE COMPONENT
 T_{es} ENGINE SETTING TORQUE
 T_{et} ENGINE TARGET TORQUE
 T_{ea} ENGINE ACTUAL TORQUE
25 ΔT DEVIATION SIGNAL
 FIG. 10
S4 ASSIST PUMP SWASH PLATE CONTROL MEANS
38 ASSIST PUMP INLET PRESSURE P_{in}
39 ASSIST PUMP OUTLET PRESSURE P_{out}
30 **37** ACCUMULATOR PRESSURE P_{ac}
D4 ASSIST REQUEST TORQUE
 ASSIST TORQUE
 ASSIST
 CHARGE
35 **81** ASSIST PUMP DIFFERENTIAL PRESSURE
 ACQUIRING MEANS DIFFERENTIAL PRESSURE
 MOTOR ACTION
 PUMP ACTION
 ASSIST UPPER LIMIT TORQUE
40 LOWER LIMIT LIMITER
 UPPER LIMIT LIMITER
 CHARGE UPPER LIMIT TORQUE
 ACC PRESSURE
 ΔP ASSIST PUMP DIFFERENTIAL PRESSURE
45 CALCULATE ASSIST SWASH PLATE ANGLE ϕ_{as}
 ASSIST PUMP MAXIMUM CAPACITY
 TORQUE EFFICIENCY
 CALCULATE CHARGE SWASH PLATE ANGLE ϕ_{ch}
10 ϕ ASSIST PUMP SWASH PLATE ANGLE ϕ
50 FIG. 11
43 BOOM LOWERING PILOT PRESSURE P_{bd}
D4 ASSIST REQUEST TORQUE
12 UNLOAD VALVE
13 ACCUMULATOR REGENERATION VALVE
55 FIG. 12
 PUMP LOAD RATIO
 ENGINE SETTING TORQUE
 MAIN PUMP LOAD TORQUE
 ENGINE TARGET TORQUE
60 ASSIST TARGET TORQUE
 TIME
 FIG. 13
 CORRECTION COEFFICIENT
 ENGINE LOAD RATIO
65 FIG. 14
 CORRECTION COEFFICIENT
 ENGINE LOAD RATIO

25

FIG. 15

CORRECTION TORQUE
ACCUMULATOR PRESSURE

FIG. 16

TORQUE

MAIN PUMP LOAD

ENGINE SETTING TORQUE

ENGINE SPEED

FIG. 17

101 ENGINE TARGET TORQUE CALCULATING
MEANS

ENGINE TARGET TORQUE CALCULATION TASK

31 ENGINE CONTROLLER

33 FRONT PUMP PRESSURE P_f 34 REAR PUMP PRESSURE P_r

ENGINE TARGET TORQUE

ENGINE ACTUAL TORQUE

TORQUE COMMAND VALUE OF ASSIST PUMP

ENGINE ASSIST TORQUE

CHARGE TORQUE

33, 34 PUMP PRESSURE SENSOR

102 SUBTRACTER

103 CONTROL OPERATION UNIT

106 SWITCH

 P_{on} , P_{off} SPECIFIED PRESSURE

The invention claimed is:

1. A hydraulic system and control device comprising:

a main pump driven by an engine and supplying hydraulic
oil to a hydraulic circuit;a variable capacity assist pump coupled to an engine or a
main pump and having both functions of a pump and a
motor;an accumulator provided to be capable of communicating
with the assist pump, and accumulating hydraulic
energy;

an accelerator means for inputting engine setting torque;

an engine actual torque acquiring means for detecting or
calculating engine actual torque;an engine control means for controlling the engine actual
torque; andan assist pump control means for controlling a capacity of
the assist pump and switching between an assist mode
for assisting the engine with the motor function of the
assist pump and a charge mode for accumulating pres-
sure in the accumulator with the pump function of the
assist pump, wherein

the assist pump control means includes:

a main pump load torque calculating means for calcu-
lating main pump load torque applied to the main
pump;an engine target torque calculating means including a
low pass filter for separating a smooth torque com-
ponent from the main pump load torque and setting,
as an engine target torque, a minimum of the smooth
torque component and the engine setting torque;an assist target torque calculating means for calculating
an assist target torque from a difference between the
main pump load torque and the engine target torque;
anda function for controlling the capacity of the assist
pump and controlling the switching of the assist
mode and the charge mode on the basis of the assist
target torque.

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2. The hydraulic system and control device according to
claim 1, wherein

the assist pump includes:

a swash plate for variably adjusting a pump capacity;
anda swash plate angle adjusting unit that adjusts an angle
of the assist pump swash plate, and

the assist pump control means includes:

an accumulator pressure detecting means for detecting
accumulator pressure of the accumulator;an assist pump differential pressure acquiring means for
detecting inlet pressure and outlet pressure of the
assist pump and thereby calculating assist pump
differential pressure;an assist torque calculating means for multiplying the
assist target torque with an engine load ratio, which
is calculated by dividing the engine target torque by
the engine setting torque, to obtain assist torque as
feed-forward torque;an engine torque feedback control means for calculat-
ing assist correction torque on the basis of a devia-
tion signal obtained by feeding back the engine
actual torque to the engine target torque;an adder that adds up the assist torque calculated by the
assist torque calculating means and the assist cor-
rection torque calculated by the engine torque feed-
back control means, thereby obtaining assist request
torque; andan assist pump swash plate control means for receiving
inputs of the assist request torque, the accumulator
pressure, and the assist pump differential pressure to
calculate an assist pump swash plate angle and
thereby outputting an assist pump swash plate com-
mand and controlling the assist pump swash plate
angle to smooth the engine actual torque.3. The hydraulic system and control device according to
claim 2, wherein

the assist torque calculating means includes:

a divider that divides the engine target torque by the
engine setting torque to calculate the engine load
ratio;a correction coefficient setter that adjusts the assist
torque to increase when the engine load ratio is high
and adjusts the charge torque to increase when the
engine load ratio is low; anda multiplier that multiplies the assist target torque with
an output of the correction coefficient setter to cor-
rect the assist target torque.

4. A working machine comprising:

a machine body hydraulically driven;

a working device mounted on the machine body; and

the hydraulic system and control device according to
claim 1 provided for the machine body and the working
device, whereinthe accumulator of the hydraulic system and control
device includes a function of accumulating and dis-
charging brake energy of the machine body and posi-
tion energy of the working device.

5. A hydraulic system and control device comprising:

a main pump driven by an engine and supplying hydraulic
oil to a hydraulic circuit;a variable capacity assist pump coupled to an engine or a
main pump and having both functions of a pump and a
motor;an accumulator provided be capable of communicating
with the assist pump, and accumulating hydraulic
energy;

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a accelerator means for inputting engine setting torque;
 an engine actual torque acquiring means for detecting or
 calculating engine actual torque;
 an engine control means for controlling the engine actual
 torque; and
 an assist pump control means for controlling a capacity of
 the assist pump and implementing switching between
 an assist mode for assisting the engine with the motor
 function of the assist pump and a charge mode for
 accumulating pressure in the accumulator with the
 pump function of the assist pump, wherein
 the assist pump control means includes:
 a main pump load torque calculating means for calcu-
 lating main pump load torque applied to the main
 pump;
 an engine target torque calculating means including a
 low pass filter for separating a smooth torque com-
 ponent from the main pump load torque and setting,
 as an engine target torque, a minimum of the smooth
 torque component and the engine setting torque;
 a subtracter that calculates a deviation between the
 engine target torque and the engine actual torque;
 a control operation unit that subjects an output of the
 subtracter to PID operation processing to obtain a
 torque command value of the assist pump;

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a pump pressure sensor that detects main pump pres-
 sure;
 a switch that implements switching to set the torque
 command value of the assist pump to zero when the
 main pump pressure is higher than specified pressure
 and select an output of the control operation unit and
 set the output as the torque command value of the
 assist pump when the main pump pressure is lower
 than the specified pressure; and
 a function for controlling the capacity of the assist
 pump on the basis of the torque command value and
 controlling the switching of the assist mode and the
 charge mode.

6. A working machine comprising:
 a machine body hydraulically driven;
 a working device mounted on the machine body; and
 the hydraulic system and control device according to
 claim 5 provided for the machine body and the working
 device, wherein
 the accumulator of the hydraulic system and control
 device includes a function of accumulating and dis-
 charging brake energy of the machine body and posi-
 tion energy of the working device.

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